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CONTENTS

ERRATA

Page 185, paragraph 9, line 3: (*see accompanying report*) should read (*see Section I*).

Page 263, pagination in Table of Contents: "Seasonal changes in availability" should be p. *274*; and "Annual variations in weight of individual herring" should be p. *276*.

Page 357, line 14: The heading *PERSOPSIDÆ* should read *PERCOPSIDÆ*.

Page 666: Beginning with "Gambier Bay" and ending with "Grant Island" omitting "Gardner Point", "Gilbert, Charles H", "Glacier Spit", "Goose Island, Icy Strait", and "Grant Cove" the paging of 38 localities is wrong in that the digit next to the margin for each of these entries was dropped one line.

Page 667: *Hyadburg Bay* should be *Hydaburg Bay*.

Page 668: *Killuda Bay* should be *Kiliuda Bay*.

Page 668: *Lynch Canal* should be *Lynn Canal*.

TEMPERATURE AND THE SHELL MOVEMENTS OF OYSTERS [1]

By A. E. Hopkins, Ph. D., *Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

The influence of temperature on the physiology of feeding in the oyster was studied by Galtsoff (1928), who found that the rate at which the gill mechanism pumps food-bearing water depends upon the temperature of the water, and that not only does this rate of pumping become slower with decreasing temperature, but at about 6° C. it actually ceases and the oyster is unable to feed. During this hibernation period induced by low temperature, it may be that cessation of flow of water through the gills is only one of the important changes in behavior. All physico-chemical activities are probably slow at this time.

In the oyster, feeding is limited not only by the rate at which the gill mechanism acts but also by the shell movements. Feeding occurs at temperature conditions favorable to gill activity only if the shells are open, for obviously water can not enter when the valves are pressed tightly together. The question arises as to what environmental factors may influence shell movements. In a work on the effect of sulphite pulp mill waste liquor on oysters by Hopkins (1931), it was shown that the presence of this substance in the water caused the Olympia oyster (*Ostrea lurida*) to remain closed more of the time than specimens in uncontaminated water. The same substance was demonstrated by Galtsoff (1931), to reduce the rate of pumping of water by the gills of both *O. lurida* and *O. gigas*. The mechanisms controlling the activity of both the gill mechanism and the adductor muscle appear to be highly sensitive to environmental factors. Since both of these mechanisms are directly concerned with the feeding habits of the oyster, it is important that they be clearly understood.

In some experiments on the effect of sulphite liquor on the Olympia oyster, the shell movements of the control specimens were recorded by means of kymographs, and thermograph records of water temperature were kept. Several such series, each of from 5 to 30 days' duration, were obtained. These records show a significant correlation between water temperature and shell activity. In the following pages certain of these results are presented and analyzed. That these conclusions are

[1] Approved for publication Nov. 25, 1930.

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probably applicable to the eastern oyster (*O. virginica*) also, is suggested by the similarity between the behavior of this species (recorded without continuous thermograph records) and that of the Olympia oyster.

METHOD

The method of recording shell movements with the kymograph was similar to that of Galtsoff (1928). The specimens were set on a plaster of Paris base and immersed in an aquarium of about 3 liters capacity. Two specimens were in each aquarium. Freshly pumped sea water was running constantly. The recording levers were of celluloid strips, and the weight of the end carried by each oyster was so counterbalanced that there was no noticeable effect on the specimen. A long paper kymograph carrying a paper about 2 meters long was employed.

The bulb of the thermograph was immersed in the water of the aquarium close to the oysters. The large size of the bulb was the source of a certain amount of error in the method. It extended from end to end of the aquarium, and while inflowing water of a changed temperature might strike a specimen and produce a reaction, it would be some time before the temperature throughout the chamber would be different enough to show a change on the record. The temperature chart showed what amounted to an average temperature in the aquarium, and for this reason would be relatively sluggish. In spite of this inaccuracy, however, the results are clear.

EXPERIMENTS WITH OLYMPIA OYSTERS (*OSTREA LURIDA*)

NUMBER OF HOURS OPEN PER DAY

Nelson (1921) found that oysters remained open an average of 20 hours per day, while Galtsoff (1928) obtained an average of 17 hours and 7 minutes. Such a discrepancy is probably due to environmental factors. Galtsoff noted that one specimen remained tightly closed for 67 hours while the temperature was between 0.5° and 1.6° C. If temperature has a marked influence on shell movement, the difference between the results of Galtsoff and Nelson becomes clear.

In Table 1, the data obtained with 18 specimens of *Ostrea lurida* are presented. During most of the tests the temperature was between 14° and 17° C., and these oysters were open a large part of the time. All results together show that, in spite of marked temperature fluctuations in certain cases, the oysters were open an average of 20.45 hours per day. Eliminating those series in which the temperature was very changeable, and one series in which the water was contaminated for a while, the remaining 12 specimens were open an average of 21.9 hours daily. Even when all of the results are considered the oysters were open and presumably feeding over 20 hours per day in spite of unfavorable conditions in certain cases.

In the following section the unfavorable temperature conditions in the above cases are discussed.

TABLE 1.—*Showing length of time which Olympia oysters remain open*

Experiment	Specimen	Hours open	Days recorded	Average number of hours open per day
No. 1	No. 1	90.25	5	18.05
Do	No. 2	103.20	5	20.64
Nos. 2 and 3	No. 3	558.96	34	[1]16.44
Do	No. 4	675.24	34	[1]19.86
Nos. 8 and 9	No. 3	309.23	17	[1]18.19
Do	No. 4	317.56	17	[1]18.68
Nos. 12 and 13	No. 3	188.80	8	23.60
Do	No. 4	186.96	8	23.37
Nos. 16 and 17	No. 3	435.20	20	21.76
Do	No. 4	433.20	20	21.66
Nos. 18 and 19	No. 3	603.00	30	[2]20.10
Do	No. 4	510.00	30	[2]17.00
Nos. 20 and 21	No. 3	695.97	33	21.09
Do	No. 4	702.57	33	21.29
Nos. 22 and 23	No. 3	688.51	31	22.21
Do	No. 4	675.18	31	21.78
Nos. 24 and 25	No. 3	463.20	20	23.16
Do	No. 4	462.00	20	23.10
Total		8,099.03	396	20.45
Totals, after elimination of experiments 2-3, 8-9, and 18-19		5,125.04	234	21.90

[1] Low proportion of time open due to temperature fluctuations.
[2] Low proportion or time open due to contamination.

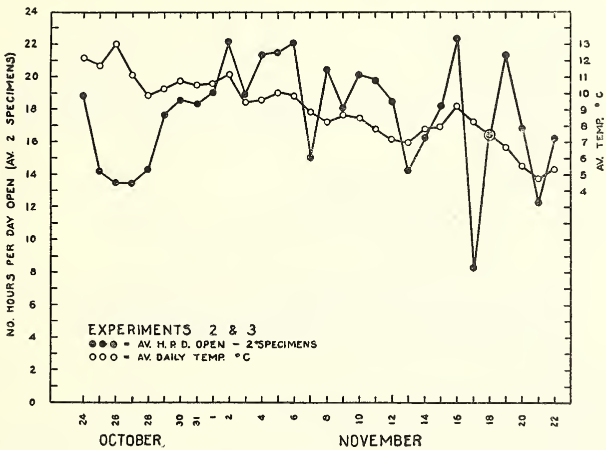

FIGURE 1.—Showing the average number of hours that two specimens of *Ostrea lurida* were open on each of 29 days, and the daily temperature of the water (average of 24 hourly readings)

EFFECT OF TEMPERATURE

That some sort of relationship exists between the temperature of the water and the length of time oysters remain open is indicated in Figure 1, in which the averaged data of the two specimens of experiments Nos. 2 and 3 (Table 1) are presented graphically. On the same graph are given the average number of hours which the two specimens were open on each of the 30 days of the experiment and the average temperature for each day calculated by averaging the 24 hourly temperature readings. The series

was begun during the relatively warm weather of October and continued until November 22, when the temperature of the water had fallen to about 5° C., or hibernating temperature, according to Galtsoff.[2] After about the first week when the specimens were not open as much as expected, it will be observed that the curves of shell activity and average temperature are suggestively parallel. Beginning at about November 1, when the temperature was about 10° to 11° C., and the specimens were open something over 20 hours daily, there is a progressive decline until at the end the temperature is only 5° C. and the specimens open only about 15 hours daily. Roughly, then, for with only two specimens considered in this manner a precise statement can not be made, a drop in average daily temperature of 5° C. over about 20 days was accom-

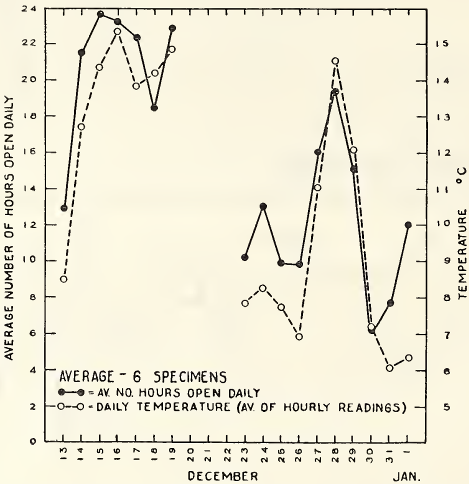

FIGURE 2.—Showing the parallel between the number of hours open daily of six specimens (*O. lurida*) and the average daily temperature. Records for three days were lost

panied by a lowering in hours open daily of about 5, or 25 per cent. These same results are calculated below in a different manner.

At best the above conclusion is only suggestive, but it is important in at least one respect, namely, that at the hibernating temperature (6° C.) during the last three days the oysters were not continually closed.

Another series (8 and 9, Table 1) shows more strikingly this relationship between shell activity and temperature. In this experiment one kymograph sheet was unfortunately lost, and there is a break in the records. (Fig. 2.) During part of the time the inflowing water was slightly heated by passing it through a lead coil which was immersed in heated water. This heating equipment was just being installed and did not work satisfactorily at first, so there are periods during which the water was heated and other periods when the temperature was low. The curves of temperature and

[2] Unpublished manuscript in the files of the Bureau of Fisheries.

amount of time open show clearly parallel fluctuations. These temperature changes are much more rapid than those shown in Figure 1, and the effect on the activity of the specimens much greater. During the first few days a rise of 7° C. was accompanied

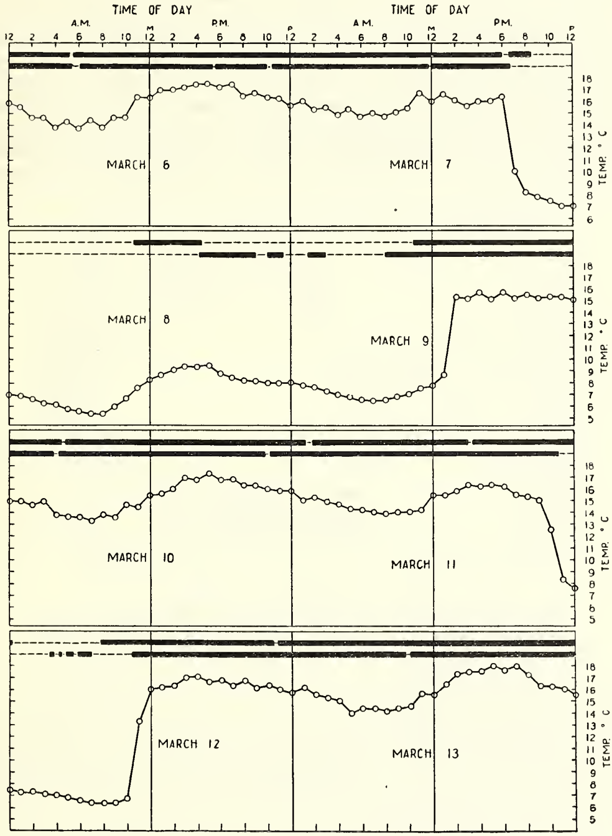

FIGURE 3.—Showing record of shell movements of two specimens of *O. lurida* and hourly temperature readings during eight days. Heavy horizontal lines represent records of oysters when open; broken lines indicate that shell was closed. A sudden drop in temperature caused the specimens to close, while a rise caused them to open

by an increase of 10 hours per day open; near the end of the test a 7.5° rise produced an increase in hours open daily of nearly 10. At the minimum temperature of 6° to 8° C. the oysters were open only about 6 hours, while at the maximum of slightly over 15° C. they were open over 23 hours per day, or nearly four times as long.

From the above two cases it appears that change of temperature is more important in affecting the length of time which Olympia oysters remain open than the degree of temperature itself. In Figure 3 the records of two specimens are reproduced in brief to illustrate the direct effect of changes in temperature of the water.

The figure represents the record of two specimens as heavy, solid lines when the shells were open and light, broken lines when closed. The hours of the day are shown as abscissae and the degrees of temperature as ordinates. During the first day the temperature was fairly high and the specimens were mostly open, but near the end of the second day (Mar. 7) the temperature fell from about 16° C. to 7° or 8° C., due to stopping of the heater, and the specimens closed. On the following day (Mar. 8), the specimens opened for a while following a rise of a few degrees in temperature of the water, but did not remain open. On March 9 they acted similarly, but remained open

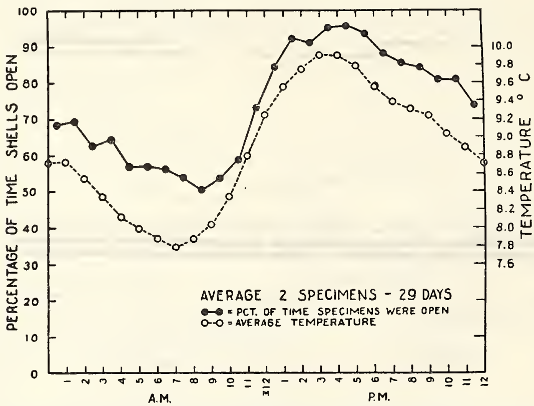

FIGURE 4.—Graph showing shell activity of the same two specimens as in Figure 1. The percentage of time open at each hour of the day over the 29-day period is plotted. Average temperature readings for each hour during the same period are plotted to show the regular daily temperature fluctuation

due to the sharp rise in temperature. During the next four days a repetition of this occurred, as shown in the figure.

Many examples such as this are at hand, but their presentation is unnecessary. The closing of the oyster, as a result of lowering of temperature and opening following rise in temperature, both appear to be responses to the stimulation of temperature change, as is discussed further below.

DIURNAL VARIATION IN SHELL BEHAVIOR

It was pointed out by Nelson (1921) that oysters (*O. virginica*) are open less at night than during the day, but he did not consider that this might be due to temperature. Galtsoff (1928) was able to observe no diurnal variation in shell activity, but his temperature records showed no considerable diurnal variation.

In the present investigation not only was there a marked diurnal variation in the amount of time oysters (*O. lurida*) remained open, but also this could be directly correlated with temperature fluctuation.

When the results obtained with the two specimens in experiments Nos. 2 and 3 (Table 1, fig. 1) are plotted according to time of day, a diurnal wave is produced. In Figure 4 the percentage of time that the specimens were open at each of the 24 hours of the day during the entire period (29 days) is plotted. From 4 to 5 p. m., for example, the oysters were open during 95 per cent of the possible 29 hours at this time. Similarly temperature is plotted as the average of the readings at each hour during the period. The resultant graph represents the records of 29 days presented as a single average day. The curves of temperature and percentage of time open are almost identical, although the average daily difference in temperature between trough and crest of the diurnal wave is only 2.1° C. The specimens, however, at the trough of the wave were open only about 50 per cent of the time, and at the crest 95 per cent. Were it not for the fact that the two waves are so closely similar, in spite of individual differences in the behavior of the oysters, it might seem that other factors, such as

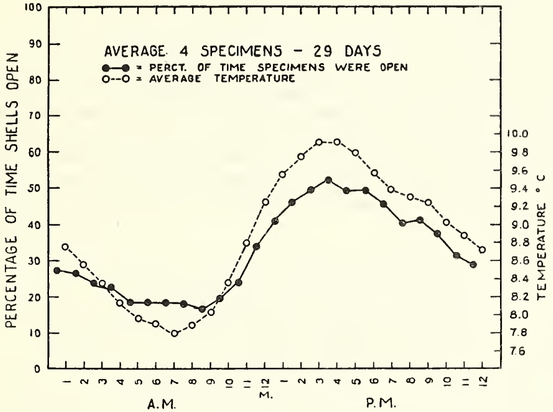

FIGURE 5.—Graph showing diurnal shell activity of four oysters. The percentage of time open during each hour of the day over 29 days is plotted along with the average temperature hourly over the same period. Although the specimens are closed more than those shown in Figure 4, due to presence of sulphite liquor in the water, the parallel between temperature and shell activity is clear

light, might be the cause of the variation. While it is probable that light has such an effect and may have influenced the results to some degree, it is obvious that temperature variation is the primary stimulating agent.

In the same series with the above were four other specimens in dilute solutions of sulphite liquor, and which, because of this, did not remain open as many hours per day as the normal oysters. The results of these four specimens are similarly presented (fig. 5), for their number tends to overcome the variations due to individual differences. Although the curve is lower in percentage of time open, it is definitely of the same character as the accompanying temperature curve. While the maximum temperature difference of the curve was 2.1° C., there was a 32 per cent difference in time the oysters were open.

The relatively great effect of a small average difference in temperature, as in Figure 4, as compared to the lesser effect of the greater change of temperature over

a long period, as in Figure 1, indicates that it is the rapidity of the change which determines the oyster's reaction. From all of the foregoing results it may be concluded that a rise in temperature causes oysters to open, while a drop causes them to close. It is of importance to determine how sensitive the oyster is to temperature changes under different conditions, that is, does a certain temperature change at a high temperature produce the same reaction as the same change at lower temperatures?

In an effort to answer this question partially from the existing results, a table (Table 2) was prepared, consisting of data similar to those shown in Figure 4. Several series, or portions of series, were selected to cover the widest available temperature range. The average hourly temperature values and percentages of time open are given in parallel columns for each series. Maxima and minima of the diurnal waves are italicized, except in one case in which the individual variation is too great to be sufficiently eliminated by the few days' duration. The average temperatures of the several series range from about 5° to about 16° C. The maxima and minima are repeated at the bottom of the table, and the difference between them determined in each case. The average temperature difference between trough and crest is close to 2° C. in most cases, so that 2° C. may be considered the standard change in temperature the effect of which it is desired to determine. In order to bring all the results to this basis, the difference between maximum and minimum of the time open wave, or the amount of increase in time open following the given temperature rise, was calculated by simple proportion to conform to a 2° C. difference, that is, in the first column the temperature difference is 2.87 and the time open difference 88.4 per cent. Then to correct the latter to a 2° C. change, $2:2.87=x:88.4$; $x=61.6$ per cent, which may be employed as representing the reaction to a rise of 2°, although this may not be strictly accurate.

In Figure 6 is a graph showing these results (solid points) as the increase in percentage of time open following the 2° C. rise in temperature during the average day (ordinates) plotted against the maximum value of the temperature wave (abscissae). It will be observed that these results fall remarkably well, considering great individual variations, into alignment. At low temperatures a change of 2° C. is accompanied by a great change in the length of time the specimens remain open; at high temperatures (14° to 17° C.) the same temperature change produces scarcely any change in the percentage of time the specimens remain open. In brief, the extent of the oyster's reaction to such a change in temperature of the medium is a function of the existing temperature, and is greater the farther the basic temperature from the optimum. On this curve there are not enough points to permit mathematical analysis. The ideal line may well be actually curved, especially as it approaches the optimum and also near the other end.

In contrast to the above, on the same chart (fig. 6) the results of the same tests are plotted (circles) as the percentage of time the specimens were open during the entire time against the average temperature for the same period. If a direct relationship exists between temperature, as such, and the length of time open, these points should also fall into a definite line. This is not the case, for although the points might be considered as falling about such a line, the variation is tremendous, and also a certain amount of alignment would be expected, due to the difference in sensitivity at different temperatures. The contrast between the two sets of points, representing the same actual data, is striking, and demonstrates that the influence of temperature on shell movement of this type is more a matter of sensitivity to temperature change than of temperature as such.

TABLE 2.—*Effect of temperature on percentage of time oysters remain open*[1]

Time	Series 1 (3 days)		Series 2 (15 days)		Series 3 (4 days)		Series 4 (29 days)		Series 5 (14 days)	
	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open
	° C.		° C.		° C.		° C.		° C.	
12 p. m.	5.03		7.19		8.15		8.72		10.37	
1 a. m.	5.10	71.7	7.26	71.0	8.16	100.0	8.75	68.5	10.36	64.3
2 a. m.	4.93	50.0	7.09	71.6	8.08	100.0	8.55	69.5	10.13	62.5
3 a. m.	4.67	48.3	6.90	65.0	7.94	100.0	8.34	62.5	9.88	55.7
4 a. m.	4.50	33.3	6.74	62.8	7.82	92.0	8.12	64.5	9.60	58.0
5 a. m.	4.17	20.0	6.55	57.2	7.78	100.0	7.96	57.0	9.51	54.0
6 a. m.	4.07	8.3	6.47	52.6	*7.76*	*96.0*	7.89	57.0	9.42	63.0
7 a. m.	*3.80*	*11.6*	*6.40*	*46.0*	7.79	95.0	*7.80*	*56.3*	*9.31*	*67.8*
8 a. m.	3.80	13.3	6.47	34.5	7.84	94.0	7.88	53.8	9.39	71.0
9 a. m.	3.90	1.7	6.61	37.3	7.98	84.0	8.03	50.5	9.55	65.3
10 a. m.	4.73	13.3	6.94	40.6	8.06	77.0	8.35	53.6	9.86	66.0
11 a. m.	5.50	25.0	7.39	48.5	8.38	85.0	8.80	58.8	10.32	70.2
12 a. m.	6.23	88.3	7.83	63.0	8.64	90.0	9.24	73.2	10.75	82.3
1 p. m.	6.40	100.0	8.14	80.5	8.82	100.0	9.54	84.3	11.05	90.0
2 p. m.	*6.67*	*100.0*	8.37	85.8	8.85	90.0	9.75	91.7	11.24	94.5
3 p. m.	6.50	100.0	*8.48*	*88.5*	8.65	97.5	*9.90*	*91.0*	11.43	93.0
4 p. m.	6.37	95.0	8.36	95.2	8.50	100.0	9.90	95.0	*11.55*	*94.5*
5 p. m.	6.07	98.3	8.18	96.2	8.27	100.0	9.78	95.5	11.50	94.5
6 p. m.	5.60	96.7	7.99	96.0	8.17	100.0	9.57	93.3	11.28	89.3
7 p. m.	5.43	88.3	7.79	93.5	8.22	100.0	9.38	88.0	11.08	81.8
8 p. m.	5.37	96.7	7.70	95.0	8.12	100.0	9.30	85.5	11.02	74.2
9 p. m.	5.33	100.0	7.64	94.6	8.12	100.0	9.24	84.3	10.98	73.0
10 p. m.	5.20	95.0	7.43	86.5	8.17	97.5	9.03	80.7	10.74	75.5
11 p. m.	5.13	80.0	7.29	85.3	8.17	90.0	8.88	80.8	10.59	75.0
12 p. m.	5.03	73.3	7.19	76.8	8.15	100.0	8.72	73.6	10.37	68.5
Average	5.18	62.84	7.38	71.87	8.18	94.50	8.86	73.73	10.46	74.34
Maximum	6.67	100.0	8.48	88.5	---------	---------	9.90	91.0	11.55	94.5
Minimum	3.80	11.6	6.40	46.0	---------	---------	7.80	56.3	9.31	67.8
Difference	2.87	88.4	2.08	42.5	---------	---------	2.10	34.7	2.24	26.7
Difference in per cent time open calculated for temperature difference of 2° C.	---------	61.6	---------	40.9	---------	---------	---------	33.0	---------	23.8

Time	Series 6 (12 days)		Series 7 (12 days)		Series 8 (18 days)		Series 9 (18 days)		Series 10 (7 days)	
	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open	Average temperature	Average per cent time open
	° C.		° C.		° C.		° C.		° C.	
12 p. m.	12.44		13.46		14.75		14.76		16.50	
1 a. m.	12.47	92.8	12.52	97.7	14.80	96.7	14.78	98.6	16.17	95.0
2 a. m.	12.28	92.5	12.40	99.5	14.47	92.4	14.47	97.8	16.00	99.2
3 a. m.	12.08	93.3	12.25	100.0	14.38	93.6	14.36	96.4	15.85	100.0
4 a. m.	11.76	93.3	12.19	94.5	14.17	93.6	14.17	91.9	15.83	96.6
5 a. m.	11.43	95.8	11.96	95.5	14.01	92.3	13.94	95.0	15.45	91.6
6 a. m.	11.15	100.0	11.90	98.2	*13.86*	*91.8*	*13.86*	*96.1*	15.35	100.0
7 a. m.	*11.04*	*93.0*	11.65	96.8	13.95	92.2	13.91	95.8	14.87	98.3
8 a. m.	11.05	93.0	*11.21*	*85.5*	13.96	93.2	13.94	96.4	14.02	78.3
9 a. m.	11.38	95.0	11.25	81.8	14.12	94.4	14.03	98.1	*13.98*	*80.0*
10 a. m.	11.82	88.2	11.45	88.2	14.10	94.3	14.08	97.2	14.28	97.5
11 a. m.	12.30	89.0	12.41	93.2	14.54	98.7	14.50	97.5	15.76	100.0
12 a. m.	12.88	88.3	13.07	94.5	15.04	98.3	15.02	99.2	16.77	98.3
1 p. m.	13.51	99.2	13.37	99.5	14.99	100.0	15.56	98.9	17.17	99.2
2 p. m.	13.97	98.7	14.14	93.6	15.77	99.0	15.80	96.6	17.31	95.7
3 p. m.	14.02	96.0	14.21	99.1	15.71	100.0	15.77	99.4	*17.39*	*100.0*
4 p. m.	14.06	100.0	*13.82*	*98.6*	*15.84*	*98.0*	*15.94*	*100.0*	16.86	97.8
5 p. m.	*14.22*	*100.0*	13.00	96.4	15.76	95.6	15.79	99.2	15.70	94.3
6 p. m.	14.12	96.3	13.27	93.2	15.69	94.5	15.71	98.6	16.19	88.6
7 p. m.	13.83	99.5	13.80	97.3	15.52	96.3	15.53	96.7	16.99	95.5
8 p. m.	13.67	100.0	13.79	97.7	15.37	96.7	15.36	95.6	17.03	96.4
9 p. m.	13.22	100.0	13.75	98.6	15.48	89.2	15.47	97.5	16.97	97.8
10 p. m.	12.97	99.5	13.77	98.6	15.09	97.8	15.09	97.5	16.98	98.6
11 p. m.	12.69	96.7	13.64	95.0	15.18	94.7	15.18	97.5	16.77	97.8
12 p. m.	12.44	96.6	13.46	96.8	14.75	94.5	14.76	95.0	16.50	95.0
Average	12.68	95.70	12.84	95.40	14.85	71.40	14.88	97.17	16.09	95.48
Maximum	14.22	100.0	13.82	98.6	15.84	98.0	15.94	100.0	17.39	100.0
Minimum	11.04	93.0	11.21	85.5	13.86	91.8	13.86	96.1	13.98	80.0
Difference	3.18	7.0	2.61	13.1	1.98	6.2	2.08	3.9	3.41	20.0
Difference in per cent time open calculated for temperature difference of 2° C.	---------	4.4	---------	10.0	---------	6.26	---------	3.75	---------	11.73

[1] The table gives records of 10 series of experiments showing the percentage of time which the specimens (two in each case) were open during each of the daily hours, calculated over the entire period concerned, and the average hourly temperature during the same periods. The troughs and crests are given in italicized figures of temperature and of percentage of time open. The summarized data at the end show the results calculated on the basis of a variation of 2° C. between crests and troughs of the temperature waves. The results appear graphically in Figure 6.

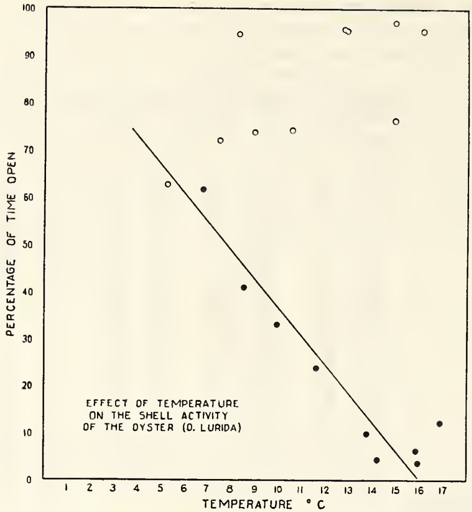

FIGURE 6.—Graphical presentation of the data given in Table 1. The circles represent the average percentage of time the specimens were open during the several series, plotted against the average temperature during the same periods. The solid points represent the increase in percentage of time open following a 2° C. rise in temperature during the average daily cycle, as described in the text

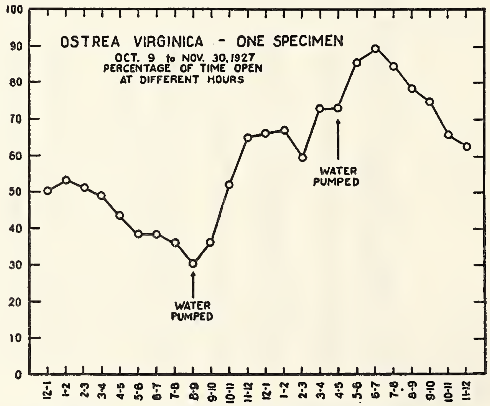

FIGURE 7.—Average day's record of the percentage of time that one specimen of *Ostrea virginica* remained open during each hour of the day during the period from October 9 to November 30, showing the clearly defined diurnal wave of shell activity

EXPERIMENTS WITH EASTERN OYSTERS (*OSTREA VIRGINICA*)

In the foregoing account it was shown that the feeding habits of the Olympia oyster are influenced by temperature changes. It is important to determine whether the eastern oyster also is sensitive in the same manner.

Several series of kymograph records of the shell movements of oysters made at Beaufort, N. C., are available. Thermograph records were not kept of the water temperature in the experimental aquaria, and any conclusion drawn must necessarily be qualified. However, these results bear a close resemblance to those above described and are presented for comparison.

Figure 7 shows the diurnal record of an oyster kept in running water from October 9 to November 30, 1927. Water was pumped twice daily into the storage tank at 8 to 9 a. m. and 4 to 5 p. m. The effect of this pumping appears as two slight

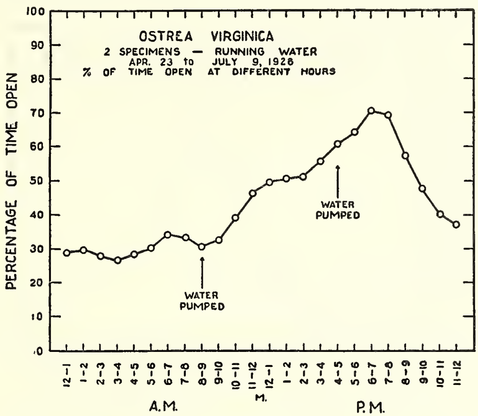

FIGURE 8.—Showing the diurnal wave of percentage of time two specimens of *O. virginica* remained open at different hours during the period of 78 days

irregularities in the record, due perhaps to the different temperature or salinity of the newly pumped water. It is apparent that the character of this curve is not greatly different from those given in Figures 4 and 5 for the Olympia oyster.

A similar and more regular record is that shown in Figure 8 representing the activity of two specimens over a period of 78 days from April 23 to July 9, 1928. In both this case and in Figure 7, the rise in percentage of time open during the day is gradual up until 6 to 7 p. m., after which it falls rapidly. This diurnal behavior is essentially similar to that of the Olympia oysters and leads to the tentative conclusion that temperature variation is at least in some measure responsible. The salt water tank at Beaufort is exposed to the sunshine, and undoubtedly the water warms up during the day and cools after sunset. The temperature of the air in the laboratory also has considerable effect on the water in the experimental tanks.

An entirely different type of curve was obtained from the records of four specimens kept in nonrunning water, closely adjacent to a window. These results are represented in Figure 9. Instead of the crest of the diurnal wave occurring at

between 6 and 7 p. m., it occurs at 11 a. m. to 12 m. It was observed that at about 10 a. m. direct sunlight struck the aquaria in which the specimens were immersed and that immediately, or within a few minutes, the oysters opened. It was thought that the bright light was responsible for the reaction; but, although light may have been concerned also, it would appear that rise in temperature was the primary stimulating agent. If it be assumed for convenience that these diurnal waves of shell activity are the effect of temperature fluctuation, as seems justified by comparison with the Olympia oysters, there are two sources of temperature variation which must be considered.

In the first place, those factors in the laboratory, such as room temperature and direct sunlight, produce temperature change in the water in the aquaria. In the case of the specimens in nonrunning water (fig. 9), the most favorable temperature conditions occur at about 12 o'clock noon. On the other hand, the water in the tank

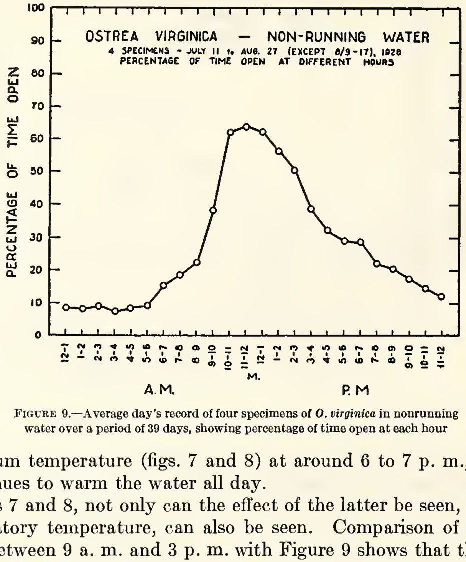

FIGURE 9.—Average day's record of four specimens of *O. virginica* in nonrunning water over a period of 39 days, showing percentage of time open at each hour

reaches optimum temperature (figs. 7 and 8) at around 6 to 7 p. m., because direct sunlight continues to warm the water all day.

In Figures 7 and 8, not only can the effect of the latter be seen, but the former, namely, laboratory temperature, can also be seen. Comparison of the portions of these curves between 9 a. m. and 3 p. m. with Figure 9 shows that the sharp rise in the curves in Figures 7 and 8 at this time, appearing as humps, is strikingly similar to the comparable portion of Figure 9.

It must be admitted that these records do not constitute as conclusive proof of the influence of temperature as the evidence cited for the Olympia oyster. However, by analogy it appears logical to assume that, in view of the similarity of the curves in the two cases, the eastern oyster behaves in a manner very similar to that of the Olympia oyster. The only other probable factor which might influence oysters in this diurnal manner is light, and there is some evidence that this may have been the source of some of the fluctuation in reactions.

That light is not the factor primarily responsible for the diurnal variation in activity is shown by the results of a series of tests made at Galveston, Tex. The shell movements of two specimens in running water were recorded for 25 days. One specimen was in a jar surrounded by a black box which effectively blocked all ordinary light rays while admitting air. The other was exposed in the laboratory. Figure 10 gives the records of the two specimens. The curves are essentially similar, showing that even in constant darkness the diurnal wave of shell activity is clearly marked.

It was pointed out that there was some difference between the results of Nelson (1921) and those of Galtsoff (1928) with regard to the length of time oysters remain open daily. The former found 20 hours to be the average, the latter only 17 hours and 7 minutes, while in the present work it was determined that Olympia oysters remain open well over 20 hours daily. These differences are only proof that the oyster is sensitive to various factors in the environment, such as temperature, as shown above,

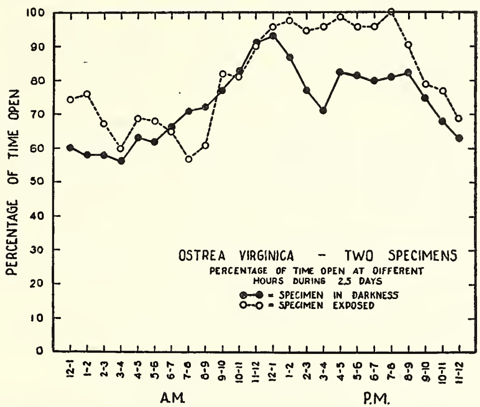

FIGURE 10.—Records of two specimens of *O. virginica*, one in darkness (solid points) and one exposed (circles), in running water at Galveston, Tex., during 25 days. Shows percentage of time each specimen was open during each of the daily hours over this period

and that the number of feeding hours daily depends upon how favorable all such conditions may be.

In contrast to the results stated above are those obtained at Beaufort with presumably normal oysters in running water which so far as known was not contaminated. In the case of one specimen (fig. 7), tested for nearly two months in October and November, the average number of hours open daily was 14.45, which is quite low. However (fig. 8) the two specimens tested under like conditions in summer for 78 days were open an average of only 10.39 hours per day. The four specimens shown in Figure 9 were in still, artificially aerated water, and remained open an average of only 6.57 hours daily. With the exception of the last mentioned, these specimens were apparently living under as favorable conditions as in the case of the tests with Olympia oysters.

In the tests made at Galveston (fig. 10) the specimen in darkness averaged 17.5 hours per day open, while the exposed oyster remained open an average of 19.4 hours

daily. It thus appears that under different conditions oysters behave decidedly differently.

Various factors may have been concerned in the low records, such as salinity variations, temperature, hydrogen-ion concentration, or the specific salts comprising the dissolved load of the water. This last will be discussed in a forthcoming paper.

SUMMARY

In the experiments with Olympia oysters it was indicated that it is not so much the existing temperature of the water which determines how long the shells remain open as it is the changes in temperature which occur. Falling temperature causes the shells to close, while opening follows a rise in temperature. The sensitivity of the Olympia oyster to temperature changes varies in an inverse manner with the general water temperature, within the range of 5° to 17° C. The latter temperature appears to be close to the optimum, for at this temperature slight changes (2° C.) produce almost no effect on the proportion of time the shells remain open. At temperatures of 4° to 6° C., when the oyster is hibernating with respect to gill activity, the shells do not remain constantly closed, but the oysters are highly sensitive to temperature change, and at such temperatures consequently remain closed a relatively high percentage of the time.

Because of this type of changing sensitivity and the diurnal temperature wave, with its trough at 6 to 7 a. m. and crest at 3 to 4 p. m., the curve of shell activity is of the same shape as the temperature wave, having trough and crest at the same times.

Similar diurnal curves of the shell activity of eastern oysters are presented, without temperature data, and it is suggested that the conclusions with regard to the Olympia oyster also apply in principle to the eastern variety.

The length of time which oysters remain open depends upon temperature and other factors. The Olympia oysters were open over 20 hours per day, while eastern oysters at Beaufort, N. C., averaged between 10 and 14 hours per day open, as contrasted to Nelson's (1921) figure of 20 hours and Galtsoff's (1928) of 17 hours and 7 minutes for oysters in New Jersey and Massachusetts, respectively.

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FLUCTUATIONS IN THE SUPPLY OF HERRING (CLUPEA PALLASII) IN SOUTHEASTERN ALASKA[1]

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CONTENTS

INTRODUCTION

A knowledge of the changes in relative abundance of the herring populations at different times and on different fishing grounds is necessary if the herring fishery is so to be regulated as to produce an optimum yield. By optimum yield is meant the maximum yield that can be taken without endangering the supply and which allows the population to maintain that level of abundance that will permanently produce either the greatest quantity or the greatest value of fish. In a previous report (Rounsefell, 1930, pp. 305–309) an analysis of the total catch figures was made, but no definite conclusions concerning abundance were reached for southeastern Alaska. The trends of abundance depended on too many factors to be determined by such a simple method. Therefore it has been necessary to use more exact methods.

As shown previously (Rounsefell, 1930, p. 272) several populations of herring are being dealt with, each of which conceivably has its own trend of abundance and therefore deserves to be studied as a unit. It is difficult, however, to determine the abundance of a single race of herring from the data of a composite fishery. Assuming that this initial difficulty be overcome, the determination of the trend of relative annual abundance is still rendered difficult by variations in the numerical strength of the annual increments to the population which may cause temporary fluctuations in abundance (Rounsefell, 1930, p. 299; 1930a). Aside from their influence on the

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trend, a knowledge of these temporary fluctuations may be of great value, as their study may eventually enable the forecasting, a year or more in advance, of the size and quantity of herring to be expected.

In pointing out the difficulties created by the presence of races and of dominant year classes, no account was taken of the difficulty of determining the abundance in the first place. Usually, for example, no reliance can be placed upon the total catch as an index of abundance, as it is subject to marked variation from economic causes and seldom represents the same amount of fishing effort. Thus if any very definite conclusions concerning abundance are to be reached, data must be collected which will represent the catch in terms of fishing effort. This is not simple if the fishing conditions are changing. A fishery once carried on during the autumn, for example, may later be conducted during the summer, and it would be unwise to assume that similar amounts of effort should represent similar catches in the two seasons without a thorough knowledge of the facts. Changes in the unit of effort itself presents another obstacle. Thus gill nets may succeed purse seines, or vice versa, and even where the same type of gear is continuously employed, a few simple changes in the net or in its manner of use, or in the fishing boat, may greatly alter the efficiency of the unit of effort.

FACTORS OTHER THAN ABUNDANCE AFFECTING THE CATCH

CHANGES IN THE SEASON

During the early years of the herring industry in southeastern Alaska, fishing was largely conducted in the fall and winter months, chiefly because the fishermen did not understand the curing of the "feedy" summer herring. About 1910 the fishermen commenced impounding the herring, thus allowing them to clean themselves of the "feed" before being salted. In 1917 the United States Bureau of Fisheries introduced the Scotch method of curing herring. In this method the fish are carefully gutted. These improvements aided in the use of the summer herring, which, being very fat, make a superior pack. The fishery thus gradually changed from a fall and early winter fishery to a summer fishery before any regulations were applied.

EFFECT OF REGULATIONS

Since the enactment by Congress of the White law in 1924 the herring fisheries have been subject to regulation by the Secretary of Commerce. The seasons open to commercial fishing in the various areas have been defined and limitations placed upon the types of gear. The regulations that concern the herring fisheries of southeastern Alaska are as follows:

Under date of December 2, 1924.

Herring fishery.—(1) Unless otherwise specified, commercial fishing for herring is prohibited in all waters closed throughout the entire year to salmon fishing.

(2) Commercial fishing for herring is prohibited during the period from January 1 to May 31, both dates inclusive, and from September 16 to December 31, both dates inclusive, of each calendar year, with the following exceptions:

(*a*) Commercial fishing for herring may be conducted from March 15 to April 15, both dates inclusive, in waters in the vicinity of Sitka within a line from Halibut Point to Cape Burunof.

(*b*) Commercial fishing for herring may be conducted from December 15 to January 15, both dates inclusive, in the waters of Seward Passage and Ernest Sound.

(*c*) Commercial fishing for herring may be conducted from January 1 to February 15, both dates inclusive, in the waters of Clarence Strait within a radius of 3 statute miles of the town of Hadley,

Tongass Narrows, Cholmondeley Sound, and Behm Canal and its tributary waters west of Bell Island to a line from Caamano Point to Point Higgins.

(3) The closed seasons herein specified for herring fishing shall not apply to any boat taking not to exceed 60 barrels of herring in any calendar week in waters open to fishing.

(4) No one shall place, or cause to be placed, across the entrance to any lagoon or bay any net or other device which will prevent the free passage at all times of herring in and out of said lagoon or bay.

Closed waters of some importance to herring fishing:

Port Frederick, northern shore of Chichagof Island: All waters east of a line drawn from Inner Point Sophia to Game Point, and all waters south of 58° 4′ north latitude. A portion of the waters closed is in the central district.

Gambier Bay, east coast of Admiralty Island: All waters west of 134° west longitude.

Wilson Cove, southwestern shore of Admiralty Island: All waters within the cove.

Whitewater Bay, southwestern shore of Admiralty Island: All waters within a line drawn from Point Caution to Woody Point.

Chaik Bay, southwestern shore of Admiralty Island: All waters east of 134° 29′ west longitude.

Warm Spring Bay, eastern shore of Baranof Island: All waters within the bay.

Hanus Bay, northeast shore of Baranof Island: All waters in the bay south of a line drawn from Point Hanus to Point Moses.

Basket Bay, east coast of Chichagof Island: All waters within the bay.

Tenakee Inlet and Freshwater Bay: All waters within a line drawn from North Passage Point to South Passage Point.

Under date of January 28, 1925.

In the period from June 1 to October 1, both dates inclusive, commercial fishing for herring is prohibited in all waters closed throughout the year to salmon fishing. The waters of Kanalku Bay, Admiralty Island, are closed throughout the year to commercial fishing for herring.

Commercial fishing for herring is prohibited during the period from March 1 to April 30, both dates inclusive, of each calendar year, except that such fishing may be conducted from March 15 to April 15, both dates inclusive, in waters in the vicinity of Sitka within a line from Halibut Point to Cape Burunof.

Under date of February 17, 1925.

Commercial fishing for herring is permitted during the period from March 1 to March 20, 1925, both dates inclusive, provided that during this period such fishing shall not be conducted on the actual spawning grounds of herring.

Under date of March 18, 1925.

Commercial fishing for herring is permitted during the period from March 21 to March 31, 1925, both dates inclusive, provided that during this period such fishing shall not be conducted on the actual spawning grounds of herring.

Under date of December 5, 1925.

(1) During the period from June 1 to October 15, both dates inclusive, commercial fishing for herring is prohibited in all waters closed throughout the year to salmon fishing.

(2) Commercial fishing for herring is prohibited during the period from January 1 to May 31, both dates inclusive, and from October 15 to December 31, both dates inclusive, in each calendar year, with the following exceptions:

(*a*) Commercial fishing for herring may be conducted from March 15 to May 15, both dates inclusive, in waters in the vicinity of Sitka within a line from Halibut Point to Cape Burunof.

(*b*) Commercial fishing for herring may be conducted from January 1 to January 15, both dates inclusive, in the waters of Seward Passage and Ernest Sound.

(*c*) Commercial fishing for herring may be conducted from January 1 to February 15, both dates inclusive, in the waters of Clarence Strait within a radius of 3 statute miles of the town of Hadley, Tongass Narrows, Cholmondeley Sound, and Behm Canal and its tributary waters west of Bell Island to a line from Caamano Point to Point Higgins.

(3) The closed seasons herein specified for herring fishing shall not apply to any boat taking not to exceed 60 barrels of herring in any calendar week in waters open to fishing.

Additional waters closed to fishing:

Kelp Bay, east coast of Baranof Island: All waters in Middle Arm, and all waters in South Arm west of 134° 57′ west longitude.

Security Bay, northwest shore of Kuiu Island: All waters within 1,000 yards of all salmon streams.

Redfish Bay, southwest shore of Baranof Island: All waters above a true east and west line passing through the southern end of the Second Narrows.

Under date of December 22, 1926.

The closed seasons herein specified for commercial herring fishing shall not apply to the taking of herring for bait purposes in waters otherwise open to fishing.

Commercial fishing for herring, except for bait purposes, is prohibited from 6 o'clock postmeridian of Saturday of each week until 6 o'clock antemeridian of the Monday following.

Commercial fishing for herring, including bait fishing, by means of any purse seine more than 1,200 meshes in depth, more than 180 fathoms in length, or of mesh less than 1½ inches stretched measure between knots is prohibited: Provided, that any purse seine may have in addition a strip along the bottom not to exceed 30 meshes in depth and of mesh not less than 4 inches stretched measure between knots. No extension to any seine in the way of leads will be permitted.

Additional waters closed to fishing:

Port Banks, off Whale Bay, west coast of Baranof Island: All waters in Port Banks.

Under date of February 17, 1927.

Seines used in commercial fishing, including bait fishing, for herring in Klawak Harbor, within a true east and west line passing through the northern extremity of Klawak Island, shall not exceed 90 fathoms hung measure in length nor 500 meshes in depth. For the purpose of determining depths of such seines measurements will be upon the basis of 1½ inches stretched measure between knots. No such seine shall have a mesh of less than 1½ inches stretched measure between knots.

Under date of October 6, 1927.

Regulation No. 2 (defining season) is amended so as to permit commercial fishing for herring with gill nets not less than 2¼ inches stretched measure between knots from October 6 through December 31, 1927, both dates inclusive, in waters otherwise open to fishing.

Additional waters closed to fishing:

Little Port Walter, east coast of Baranof Island: All waters in Little Port Walter.

Under date of September 24, 1928.

Regulation No. 2 (defining season) is amended so as to permit commercial fishing for herring with gill nets not less than 2¼ inches stretched measure between knots from October 1 to December 31, 1928, both dates inclusive, in waters otherwise open to fishing.

Under date of December 18, 1928.

Commercial fishing for herring, including bait fishing, by means of any trap is prohibited.

No herring fishing boat shall carry or operate more than one seine of any description, and no additional net of any kind shall be carried on such boat. The carrying of any additional seine or net of any kind on a boat towed by any herring fishing boat is prohibited.

Although a number of regulations have been made it is obvious that only a few really have any serious limiting effect on the fishery. The restricting of the fishery to the four months from June to September, including as it does practically all of the period when the herring are fat enough to be profitably utilized for reduction, or for the best grades of Scotch cured herring, has almost no effect on the quantity of the catch. Likewise, the effect of the closure of several bays to salmon fishing (and therefore to herring fishing) has probably been negligible, as in nearly every case the closed areas were of slight importance for herring. The 36-hour weekly closed season, in effect since 1927, is a different matter. There is little doubt that it has had some effect on curtailing the catch. Whether this short closed period actually restricts the catch in proportion to its length is dubious, however, as the boats usually

FIGURE 1.—A typical oar-propelled seine boat generally used during the early development of the herring fishery. A large steam or motor vessel towed or carried on davits two of these boats with half of the seine in each boat. When a school of fish was discovered the two seine boats were rowed around its opposite sides and the seine pursed by hand. This method was last used by the Big Port Walter plant in 1926. Taken at Big Port Walter in June, 1929

FIGURE 2.—The purse seine boat *Valencia*. This is a typical modern Diesel-powered vessel, 59 feet long with a 17-foot beam, 46 tons gross and 31 tons net, built in Tacoma in 1927, and equipped with a 90-horsepower Diesel engine. Taken at Big Port Walter in June, 1929

utilize it in prospecting for herring schools, running to distant grounds, or tanning their seines. Most of the restrictions on gear have been made more with the idea of safeguarding against possible abuses than as restrictions.

CHANGES IN THE UNIT OF FISHING EFFORT

CHANGES IN THE PURSE SEINE VESSELS

Of more importance in the study of abundance perhaps than the change in the fishing season has been the change in the unit of fishing effort. Thus the plant at Killisnoo employed, from 1882 to 1923, a Norwegian method of seining from oar-propelled seine boats (Rounsefell, 1930, p. 230). (See fig. 1.) Besides this method, beach seines were also used for a time by other operators. Soon after 1900 the first purse seines were employed for herring and so rapidly gained in favor that by 1927 the last Norwegian type of seine had disappeared.

No other methods of fishing have been of any importance in southeastern Alaska. The Killisnoo plant twice attempted to use traps but neither attempt was successful and their use is now prohibited. Gill nets are used, but chiefly by the salmon trollers as a means of obtaining very small quantities of bait.

As the purse seine has supplanted all other types of gear and has caught the bulk of the herring for many years, a study has been made of its changes in efficiency. This has been accomplished through a study of the purse-seine fleet rather than of the seine, which although it has changed somewhat in size, has not changed in shape or in method of use.

The purse-seine fleet has undergone a great change since 1922, which year marked the start of a tremendous expansion of the summer herring fishery. Since then there have been radical changes in the size and age of the vessels, the type of hulls, the horsepower relative to the size of the vessel, the type of engines, the increased use of the power seine roller, and in many less important features, all of which have added very materially to the effectiveness of the vessel as a fishing unit. In short, the unit of fishing effort—the purse-seine vessel—has changed so materially in the short space of eight years that comparisons between catches of earlier and later vessels are not valid without a knowledge of the effect of these changes.

Figure 3 shows the net tonnages of purse-seine vessels that have appeared in the fleet at some time from 1919 to 1929 plotted against the year in which they were built. It is apparent that there were two distinct periods marked by special activity in the building of these boats. The first, from 1917 to 1920, was undoubtedly due to the prosperity attending the World War. The second, from 1925 to 1928, was due to the phenomenal growth of the fish oil and meal industry. This second period of building is characterized by the adoption of the Diesel engine, which burns a very cheap semirefined oil, permitting the boats to make long trips at low cost and with less actual bulk of fuel than is the case with engines burning gasoline or distillate.

The vessels built at the beginning of the second period, in 1925, averaged 29.2 net tons as against 27.9 net tons in 1920, a slight increase. From then on the size increased rapidly, reaching an average of 41.3 net tons in 1928. The years 1927 and 1928 were poor seasons for the herring companies, resulting in the building of only three new boats in 1929. The two for which we have the tonnages average 36.5. Although this represents a decrease in size from 1928, the number is too small to give a significant average.

The size of the vessels of the fleet each year since 1923 is shown graphically in Figure 4, in which the boats are divided into four categories. Boats under 25 net

tons, comprising 60 per cent of the fleet in 1923, have entirely disappeared by 1929. Coincident with the fall of the group under 25 tons, the group from 25 to 29 tons rose from 26.5 per cent in 1923 to 39 per cent in 1925 and 1926, but in 1927 it commenced to decline, and in 1929 comprised but 22 per cent of the total. The group from 30 to 34 net tons, commencing at only 14 per cent in 1923, rose to over 37 per cent in 1926. Since then this group has declined to slightly over 27 per cent. Although boats of this tonnage still comprise 27 per cent of the fleet, the individual boats now in use are chiefly new Diesel boats built from 1925 to 1927, and the group is still increasing in efficiency through the loss of older boats and the acquisition of new. The most remarkable feature is the sudden appearance of the group composed of boats of 35 net tons and over—large, fast, high-powered vessels, well constructed and seaworthy. Appearing in 1925 and 1926 this group increased rapidly until by 1929 it included over 50 per cent of the fleet. (See fig. 2.)

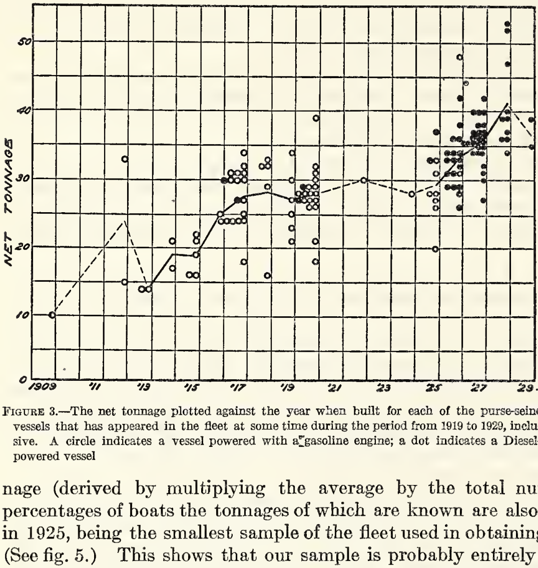

FIGURE 3.—The net tonnage plotted against the year when built for each of the purse-seine vessels that has appeared in the fleet at some time during the period from 1919 to 1929, inclusive. A circle indicates a vessel powered with a gasoline engine; a dot indicates a Diesel-powered vessel

A summation of these size changes is shown in Table 1, which gives the number of boats each year, the average net tonnage (of those of which the tonnage is known), and the calculated total net tonnage (derived by multiplying the average by the total number of boats). The percentages of boats the tonnages of which are known are also given—71.9 per cent, in 1925, being the smallest sample of the fleet used in obtaining the average tonnage. (See fig. 5.) This shows that our sample is probably entirely adequate to represent the fleet, except possibly in 1922 in which the numbers are so small that the chance for error is greatly increased. The rapid rise from an average of 23 net tons in 1922 to 34 net tons in 1929 is too great to be ignored.

TABLE 1.—*Purse seine fleet of southeastern Alaska*

Year	Number of boats	Number with tonnages known		Average net tonnage	Total net tonnage	Year	Number of boats	Number with tonnages known		Average net tonnage	Total net tonnage
		Actual	Per cent					Actual	Per cent		
1922	8	6	75.0	23.33	186.64	1926	48	48	100.0	28.42	1,364.16
1923	15	14	93.0	22.00	330.00	1927	70	69	98.6	30.65	2,145.50
1924	20	17	85.0	25.30	506.00	1928	65	64	98.5	33.34	2,167.34
1925	32	23	71.9	27.48	879.36	1929	56	55	98.2	33.71	1,887.76

In gaging the changes in efficiency of the individual boats of the fleet, it is extremely difficult to translate changes in size, speed, seaworthiness, age, etc., into terms of relative ability to deliver quantities of fish at the plant. In addition there is no assurance in comparing two types of vessels in 1929, for example, that precisely the same conditions held in 1922. In a year when fishing was conducted at a distance, speed and size might be the paramount factors; in outside waters seaworthiness would play a part; in years of scarcity, when each haul netted but few fish, the larger vessels might conceivably catch less than the smaller, because of greater difficulty in maneuvering.

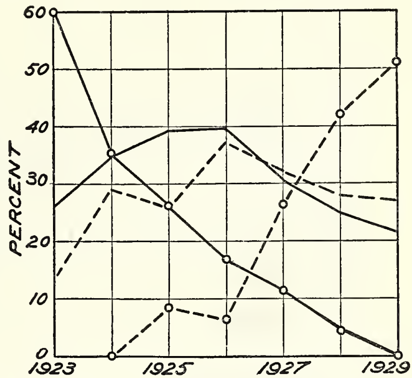

FIGURE 4.—Showing the percentages of the fleet included in different size categories from 1923 to 1929. Solid line with circles, less than 25 net tons; solid line without circles, 25 to 29 net tons, inclusive; dotted line without circles, 30 to 34 net tons, inclusive; dotted line with circles, over 34 net tons

In order to discover whether the efficiency of the vessel depends upon size, the total monthly catches have been correlated with the net tonnage of the vessel, the coefficient of correlation being calculated from ungrouped data. (Table 2.) An inspection of the table shows a great variation in the value of the coefficient of correlation. In only 6 out of 23 coefficients is the correlation significant. Of these 6, the significance of the negative coefficient based on only 9 pairs of items must be regarded as very doubtful.

TABLE 2.—*Correlation between net tonnage and total monthly catch of purse seine boats*

Month and year	Number of pairs of related items	Mean catch in barrels	Mean net tonnage	Pearsonian coefficient of correlation	Probable error of coefficient of correlation	Regression of catch on tonnage
NORTH [1]						
June, 1927	26	1, 598	30. 4	0. 803	[2] 0. 05	195. 7
June, 1928	28	2, 597	33. 4	. 427	[2] . 10	49. 2
June, 1929	18	3, 112	35. 2	—. 218	. 15	80. 6
July, 1927	23	2, 120	30. 7	. 211	. 13	44. 1
July, 1928	26	1, 647	34. 1	—. 228	. 13	21. 0
July, 1929	18	1, 674	35. 2	—. 157	. 15	36. 0
August, 1927	9	1, 671	30. 4	—. 065	. 22	10. 0
August, 1928	23	1, 398	35. 0	—. 355	. 18	40. 5
August, 1929	12	2, 815	36. 0	—. 202	. 19	64. 2
September, 1928	9	2, 022	38. 4	—. 615	[2] . 14	71. 8
September, 1929	5	4, 894	35. 4	—. 626	. 18	1, 003. 9
SOUTH [3]						
June, 1927	23	1, 940	31. 4	. 193	. 14	33. 6
June, 1928	30	3, 018	33. 3	—. 191	. 12	36. 5
June, 1929	30	2, 672	33. 3	—. 075	. 12	15. 8
July, 1927	27	2, 143	31. 3	. 059	. 13	12. 0
July, 1928	29	2, 088	33. 1	—. 246	. 12	32. 8
July, 1929	29	1, 440	33. 4	—. 178	. 12	31. 8
August, 1927	19	2, 637	31. 3	. 412	. 13	66. 1
August, 1928	29	2, 005	33. 4	—. 204	. 12	32. 4
August, 1929	34	3, 710	33. 1	. 569	[2] . 08	180. 8
September, 1927	12	3, 195	33. 0	. 469	. 15	76. 6
September, 1928	16	3, 513	33. 8	. 688	[2] . 09	134. 6
September, 1929	34	5, 344	33. 1	. 532	[2] . 08	160. 2

[1] Boats delivering to plants north of Point Ellis (Group II and III).
[2] Coefficient of correlation of probable statistical significance.
[3] Boats delivering to plants south of Point Ellis (Group I).

It appears that the changes in the values of the coefficients follow somewhat the same trend from year to year. However, a more careful inspection shows that such a conclusion is hardly justified. In the set of boats delivering to plants north of Point Ellis (Groups II and III, fig. 10) while the July and August values are quite similar, two of the June values are high and the third is low, so that no reliance can be placed on them. The values for September are based on too few items to be worthy of serious consideration. For those boats delivering to plants south of Point Ellis, it appears that there may be a significant correlation between size and catch during September, but the inconsistency of the August values makes it seem doubtful that any definite conclusions can be reached without more data.

For the set of boats north of Point Ellis there appears to be no correlation. For the set of boats south of Point Ellis there appears to be a larger coefficient of correlation with the larger catches. Table 2 shows that these larger catches were all made in August and September. This being the case it may be concluded that the reason the larger boats are more efficient at this time is principally because of their superior seaworthiness, for during the last part of August and in September the boats of this southern set fish chiefly around Cape Ommaney, where the weather is very adverse at this season of the year. If this correlation were due to the quantities of fish taken, then a similar correlation should appear in the set north of Point Ellis; but in the northern set of boats such a correlation does not appear, and in this set the larger quantities are not taken under as adverse conditions.

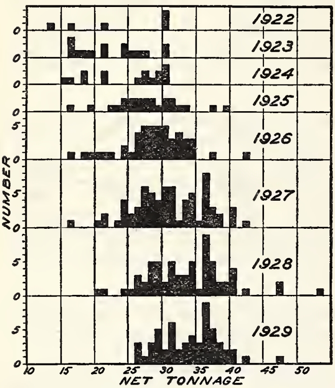

FIGURE 5.—Showing the net tonnage of every boat in the fleet for which the tonnage is known, each year from 1922 to 1929

A reason for the lack of a significant correlation between size of boat and monthly catch is suggested by Table 3 in which the daily catches are shown, during 1929, for the 4 smallest and the 4 largest vessels of the fleet. The 4 smallest vessels comprise 3 of 26 net tons and 1 of 27 net tons. The 4 largest vessels include 2 of 40, 1 of 42, and 1 of 47 net tons. Two features are of importance—one is the larger catches taken by the larger vessels, the other is the greater number of catches taken by the smaller vessels. Here is probably the answer to lack of correlation between size and total catch, the smaller vessels making up in number of catches for what the larger vessels gain by an occasional large catch.

It may be concluded from this study of the fleet that the differences in the efficiency of boats of different sizes are dependent upon too many factors to be analyzed easily, but upon the whole these differences are not sufficiently marked in the period from 1927 to 1929 to make it necessary to allow for them in an analysis of the catch per unit of fishing effort, and even though one so desired not enough is known at present to justify making such an allowance. This statement probably does not apply to the very small boats used extensively in the earlier years, especially before 1925, which certainly did not approach the recent boats in efficiency.

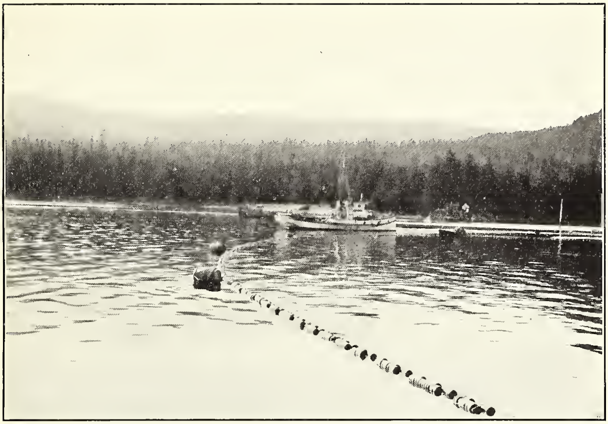

FIGURE 6.—Herring impounded at Auke Bay (area 20) to be used as fresh bait for halibut fishing. The net is set in a semicircle from the shore. Herring are often confined for a month or two in these pounds and caught as needed by a small pound seine used from a skiff. Such equipment is shown in the right center of the picture. Taken in June, 1929

FIGURE 7.—Herring saltery and reduction plant at Port Conclusion

CHANGES IN THE PURSE SEINES

Besides these changes in the boats there have been some slight changes in the purse seines. From about 170 fathoms in length a few years ago the seines gradually increased in length and depth, especially on the larger boats until some were over 200 fathoms in length. In 1926 (p. 18) a regulation was promulgated restricting seines to 180 fathoms in length and 1,230 meshes in depth. This decrease in length of a few of the larger seines is not of sufficient importance to be taken into consideration, but it may in the future serve as a restriction on the building of very large seine boats.

EFFECT OF IMPOUNDING ON THE UNIT OF EFFORT

The use of the purse-seine boat as a unit of fishing effort during the early years of the fishery is somewhat invalidated by the then prevailing practice of impounding (described in a previous report, Rounsefell, 1930, p. 231). For example the Pacific Fisherman for September, 1917, says that Alaska Herring & Sardine Co. at Little Port Walter reported enough herring impounded in the harbor to last them all season, and the Alaska-Pacific Herring Co. had approximately 12,000 barrels of herring impounded at Big Port Walter. (See fig. 6.)

Since 1925 practically no impounding has been done in southeastern Alaska (exclusive of that for bait) except in Surprise Harbor. The change has probably been due largely to several causes—as the increased carrying capacity of the newer boats; the increase in the percentage of the catch taken in deeper water and around Cape Ommaney where impounding is impracticable; and the increase in the numbers of the fleet; which, taken together with the ever increasing cruising radius, make it highly inconvenient for each seine boat to have a towboat for impounding.

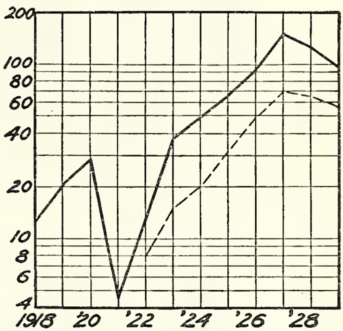

FIGURE 8.—Showing the combined capacity of all herring reduction plants (solid line), except the S. S. *Peralta* in 1927 and 1928, and the number of purse-seine boats (dotted line), plotted on a logarithmic (proportional) scale so that the slopes of the two curves are comparable (see text)

CAPACITY OF THE HERRING PLANTS

A knowledge of the variations in the capacity of the herring plants as determined by the sizes of herring needed and the quantity capable of being used is important to this study. Previous to the building of additional reduction plants in 1919, all of the herring companies (with the exception of Killisnoo) were limited in their use of herring to what they could salt or can. They fished only for herring of a size large enough to fulfill their requirements; consequently the catch per boat of this period would be in no way comparable to that of later years, even were one sure what type of gear was employed in every case.

The total capacity in tons of raw fish per hour of all of the reduction plants (except the S. S. *Peralta* in 1927 and 1928) and the number of boats fishing each year are shown in Figure 8. The two curves have been plotted on a logarithmic scale to show the relative changes. It is obvious that the relation between boats

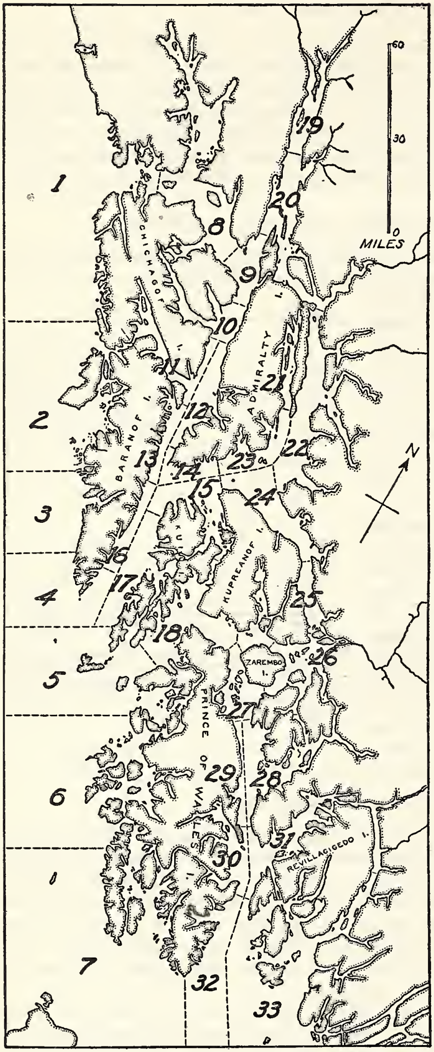

FIGURE 9.—Southeastern Alaska, showing the statistical areas used

and capacity has remained fairly constant. However, the capacity is based on the rated capacity of the press machinery. This machinery has been constantly improved, so that, whereas most of the presses of a few years ago could barely handle their rated capacity of raw fish, practically all of the newer presses (most of those now in use have been installed since 1926) can slightly exceed their rated capacity whenever occasion demands. When the installation of more efficient cookers, meal dryers, fish conveyors, etc., is considered, it can readily be comprehended that the rated capacity of the presses, our best measure of capacity, is too much in error to form an accurate basis of comparison from year to year.

All of these facts tend to show that the actual capacity of the reduction plants has increased more rapidly than the number of boats. If this be true it is self-evident that in the earlier years the plants were more apt to be confronted with an oversupply of fish. This to some extent invalidates comparisons between earlier and later years, since whenever the plants have an oversupply of herring the catch per boat fails as a measure of abundance. At such times the curve of abundance is abruptly truncated. The values obtained are minimum values, and there is no means of judging what the actual abundance may have been. Now if the capacity of the plants is raised, then at such times of great abundance the curve is truncated at a higher level; so that in making compar-

isons with earlier years it may appear that at times the fish reached a higher level of abundance than formerly, whereas the obviously higher level is but an artifact. This will, however, tend only to minimize any fall in the trend of abundance and, far from invalidating any fall which may be found to have occurred, will give it additional significance.

ANALYSIS OF CATCH RECORDS

The sources of the data herein employed are the same as those given in a previous report (Rounsefell, 1930, p. 303) and will not be repeated. In this report, however, the most use has been made of the daily catch records and not the production records, which were necessarily emphasized in the former analysis of the early years.

In analyzing the statistics for southeastern Alaska the whole region has been arbitrarily divided into 33 areas. (Fig. 9.) The boundaries between areas have been drawn as far as possible so as to pass through waters where little or no fishing occurs. This was done partly to avoid all confusion in assigning catches to their proper areas and partly so that each area would represent a natural fishing ground. By thus separating each natural fishing ground it was felt that the analysis would be more in confomity with what meager knowledge already exists concerning races (Rounsefell, 1930, p. 272), and any fluctuations due to the passage of dominant year classes might be more easily segregated and studied.

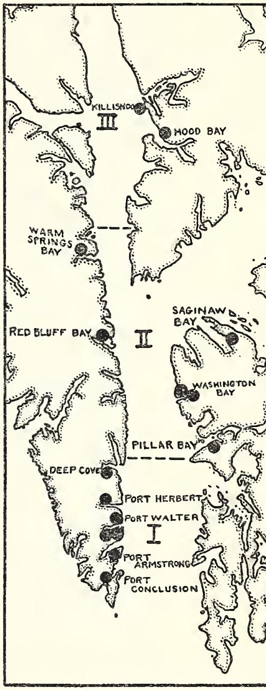

FIGURE 10.—Chatham Strait, showing the three groups into which the plants were divided for the statistical analysis

As a further refinement it was found advisable for purposes of analysis to divide the purse-seine boats into three groups according to the locations of the plants to which they delivered their catches. (Fig. 10.) Group I comprises boats delivering to plants south of Point Ellis. The boats of this group fish chiefly in area 4. Group II contains boats delivering to plants north of Point Ellis but south of Wilson Cove. These boats fish chiefly in areas 4 and 17, but are wider ranging than the boats of Group I. The boats of Group III, delivering to plants north of Wilson Cove, fish chiefly in the northern areas, especially 8, 9, and 20, and in the central Chatham Strait areas. One company maintains two plants—one located at Port Herbert in Group I, and the other located at Warm Springs Bay in Group II. The boats of this company delivered fish to either plant; therefore although they are used in studies of the combined groups, their data have not been used in the analysis of the individual groups.

CHANGES IN AVERAGE SIZE OF CATCH

The average delivery per boat as a record of abundance is subject to the same criticism as that of the total catch or the catch per week, namely, that in times of

great abundance the carrying capacity of the boat limits the size of catch so that above a certain point it is impossible to measure the variations in abundance. (See fig. 11.) In Table 3 is given the daily catches of the four largest and four smallest purse-seine boats operating during 1929. It is obvious from the table that the average size of catch would tend to rise with an increase in the size of the vessels, tending to minimize any fall due to depletion, because the larger the boat the higher the level at which the curve of catch is truncated.

Another important factor to be considered is the shift in the fishing grounds. On new grounds the average size of catch may be expected to be larger than on older grounds. Thus the constant shift of the fishery to new grounds as the older are depleted has kept up the average size of catch, obscuring and minimizing any fall in abundance. For these various reasons any decline shown by this method must be regarded as a minimum decrease and can not be regarded as showing the actual extent of depletion.

TABLE 3.—*Frequency distributions of catches of the four smallest and the four largest purse-seine vessels of fleet in 1929*

Size of catch, in barrels	Small boat frequencies					Large boat frequencies				
	Individual boats				All boats	Individual boats				All boats
0 to 39	5	9	12	6	32	6	3	8	5	22
40 to 79	5	8	12	10	35	5	4	6	----	15
80 to 119	9	6	9	6	30	6	2	9	1	18
120 to 159	10	8	2	6	26	9	3	5	4	21
160 to 199	8	7	3	5	23	3	3	3	3	12
200 to 239	6	7	4	2	19	1	2	5	2	10
240 to 279	1	2	1	6	10	2	----	2	----	4
280 to 319	8	3	----	7	18	2	3	4	----	9
320 to 359	6	1	4	4	15	3	3	1	2	9
360 to 399	5	1	1	4	11	3	2	3	----	8
400 to 439	3	3	4	8	18	2	3	1	----	6
440 to 479	1	----	----	7	8	1	4	----	2	7
480 to 519	1	9	----	1	11	----	----	----	2	2
520 to 559	1	----	----	----	1	2	----	----	2	4
560 to 599	----	1	----	----	1	----	2	1	2	5
600 to 639	----	----	----	----	----	1	2	1	----	4
640 to 679	----	----	----	----	----	----	1	----	----	1
680 to 719	----	----	----	----	----	1	----	----	----	1
720 to 759	----	----	----	----	----	1	1	----	1	3
760 to 799	----	----	----	----	----	4	----	----	----	4
800 to 839	----	----	----	----	----	1	2	----	----	3
840 to 879	----	----	----	----	----	1	1	----	----	2
1,000 to 1,039	----	----	----	----	----	----	2	----	----	2
Total number of catches	69	65	52	72	258	54	43	49	[1]26	172
Net tonnage of boat	26	26	26	27	----	40	40	42	47	----

[1] First half of season only.

In determining the general abundance by the average size of the deliveries a standard average delivery for each date was obtained by the formula:

$$s=\frac{a_1+a_2+\ .\ \ .\ \ .\ \ .+a_n}{n},$$

in which a_1, a_2, etc., are the arithmetic means of the deliveries on the given date in different years and n is the number of years. A standard curve was then obtained by smoothing these standard averages by threes, thus obtaining a smoothed average for each date, designated by S, S_1, S_2, etc.

Each month in each year was next compared with that month's portion of the standard curve by the formula:

$$\log D=\frac{(\log a-\log S)+(\log a_1-\log S_1)+\ .\ \ .\ \ .+(\log a_N-\log S_N)}{N}$$

Figure 11.—The purse boat *Lemes II*, decks awash, at Pillar Bay, with a "deck load" of herring from Douglas Island (area 20). Note the outside setting wheel atop the wheelhouse. This is being installed on all of the new boats for quick and easy maneuvering while seining. Taken July, 1929

Figure 12.—Purse seine boats awaiting their turn to unload at New Port Walter. Taken June, 1929

in which a, a_1, etc., are the averages on various days, S, S_1, etc., are the standard averages, and N is the number of days. Thus D is, for the month in question, the geometric mean of the percentages that the averages (a, a_1, etc.) of the various days are of the corresponding values on the standard curve. The average for each month in 1928 has been called 100 per cent and the monthly averages of the other years expressed as percentages of this base.

TABLE 4.—*Comparisons of average daily catches of each year with a standard daily catch curve*

Month	Geometric means of the average daily catches expressed as percentages of the standard curve				Geometric means expressed as percentages of 1928 mean			
	1926	1927	1928	1929	1926	1927	1928	1929
GROUP I								
June	90.0	64.3	94.2	78.4	95.6	68.3	100	83.2
July	132.9	76.1	78.4	53.1	169.5	97.1	100	67.7
August	124.6	70.4	54.4	78.4	229.0	129.3	100	144.1
September	93.2	71.3	69.9	83.1	133.3	102.0	100	118.9
Total	110.8	70.4	72.9	64.0	152.0	96.6	100	87.8
GROUP II								
June	90.6	71.5	97.4	97.4	93.0	73.4	100	100.0
July	118.8	73.7	70.6	91.8	168.3	104.4	100	130.0
August	114.7	71.9	61.0	70.5	188.1	117.9	100	115.5
September	-------	61.6	58.2	121.6	-------	105.8	100	209.0
Total	109.8	70.4	71.0	93.1	154.6	99.2	100	131.1
GROUP III								
June	90.0	95.5	90.4	-------	99.6	105.6	100	------
July	91.4	68.2	67.0	-------	136.4	101.8	100	------
August	135.4	40.9	42.3	-------	321.0	97.0	100	------
Total	101.7	64.0	68.1	-------	149.4	94.0	100	------

The geometric mean has been used in preference to the arithmetic mean so as to give equal weight to the same relation deviations from the standard curve. Thus an increase of 100 per cent in a number should have the same weight as a decrease of 50 per cent—in one case the number is doubled, in the other it is halved. For example, the geometric mean of 200 per cent and 50 per cent (representing a 100 per cent increase and a 50 per cent decrease) is 100 per cent, but the arithmetic mean is 125 per cent. For a detailed discussion of the use of the geometric mean see Fisher (1922).

In comparing the curves in Figure 13 it should be noted that changing the geometric means of the percentages to percentages of the 1928 mean was done only for the purpose of putting all of the curves on the same basis for comparison. These curves give the rates of change and therefore the slopes of the various portions are directly comparable.

The month of June (fig. 13) maintains practically the same level of abundance, except in 1927 in which Groups I and II show June to be distinctly lower.

The abundance during the month of July shows a consistent drop from 1926 to 1927; 1927 and 1928 are practically the same. In 1929 Group I shows a further decline, but Group II shows an equally large increase. The only conclusion to be drawn is that 1926 shows the highest level of abundance in this month.

In the month of August it is clear that 1928 shows the least abundance, 1926 the most.

1926, in September, is but slightly higher than 1929 in Group I. Group II shows September at a very high level but this is probably an artifact, for in this group, since there was no fishing during September in 1926, the high 1929 year is compared to a standard curve considerably lower than would surely be the case were 1926 included.

The curves for the whole four months' period (fig. 13) show 1926 to be at a very high level of abundance; 1927 is at a very slightly lower level than 1928. In 1929 the Group I boats show a further decline, whereas the Group II boats show a large increase. This large increase probably is due in large part (as previously explained) to the lack of data for this group during September, 1926.

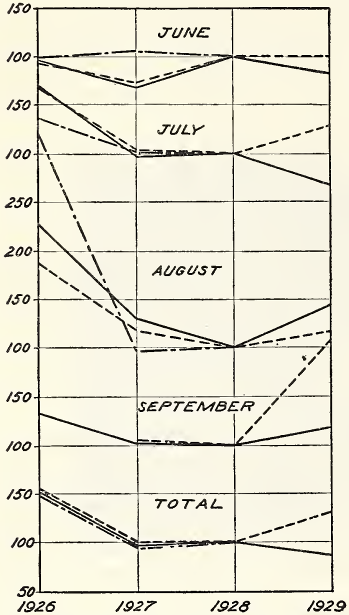

FIGURE 13.—Showing the geometric means (expressed as percentages of the 1928 mean) of the percentages that the average size of catch is of a standard curve (see text). Solid line, Group I; dotted line, Group II; broken line, Group III

From this analysis of the average size of the catches it must be concluded that 1926 shows a much higher level of abundance than the three succeeding years.

CHANGES IN NUMBER OF DELIVERIES

Another method used in this attempt to determine the general trend of abundance was a study of the number of deliveries made by each boat each week. This method entails certain errors. When the fishing is being conducted at a distance the number of deliveries will necessarily be small; while when fishing close to the plant the number of deliveries will usually be high, even though the catches may be small. During 1926 the number of deliveries each week has been multiplied by the factor 0.786, to make the data comparable to the following years in which there has been a 36-hour weekly closed season from 6 o'clock postmeridian Saturday to 6 o'clock antemeridian of the Monday following. These data were analyzed in the same manner as the daily deliveries, the average number of deliveries per week being assumed to be the average for each day within the week. Thus the standard average on each day consisted of the arithmetic average of the average number of deliveries per week of the four weeks that happened to include the particular day. The results of the computations are shown in Table 5.

TABLE 5.—*Comparisons of average number of deliveries per week of each year with a standard delivery curve*

Month	Geometric means of the average number of deliveries expressed as percentages of the standard curve				Geometric means expressed as percentages of 1928 mean			
	1926	1927	1928	1929	1926	1927	1928	1929
GROUP I								
June	94.4	79.4	92.4	126.5	102.1	85.9	100	136.9
July	121.5	81.2	94.7	76.8	128.3	85.7	100	81.1
August	96.6	85.8	90.8	84.0	106.4	94.5	100	92.5
September	81.3	85.5	83.8	127.5	97.0	102.0	100	152.1
Total	98.2	82.9	90.6	99.4	108.3	91.5	100	109.7
GROUP II								
June	71.4	83.6	108.6	137.7	66.1	77.4	100	127.5
July	108.3	96.0	101.6	86.8	106.6	94.5	100	85.4
August	91.6	88.1	97.2	74.0	94.2	90.6	100	76.2
September		86.4	73.8	121.8		117.1	100	165.0
Total	90.0	88.6	95.0	96.5	94.8	93.3	100	101.6
GROUP III								
June	119.3	55.4	100.5		118.6	55.1	100	
July	129.4	82.5	86.6		149.5	95.3	100	
August	111.6	104.8	75.0		148.9	139.7	100	
Total	119.9	77.8	86.2		139.1	90.3	100	

This method of analysis gives somewhat the same results as that in which the average size of the deliveries was used, as can readily be observed by comparing Figures 13 and 14. One marked difference occurs in the month of June in which the number of deliveries is highest in 1929. The two figures correspond quite closely in July, except for Group II in 1929, which has a high average size of catch and a low number of deliveries. The same is true in August for both the I and II groups. During August all of the groups have a high average size of catch in 1926, but the number of deliveries shows no rise in Groups I and II and only a moderate rise in Group III. The total curves for the two methods of analysis agree rather well, except that the number of deliveries in 1926 is not so high relatively as the average size of catch. This may be an artifact, however, caused by the failure of the factor 0.786, by which the 1926 data was multiplied, to give a true valuation of the change in number of deliveries caused by the lack of a weekly closed season in 1926.

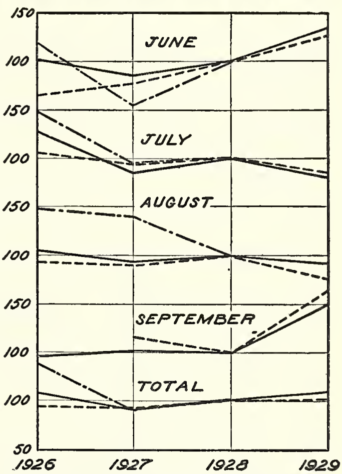

FIGURE 14.—Showing the geometric means (expressed as percentages of the 1928 mean) of the percentages that the average number of deliveries per boat per week is of a standard curve (see text). Solid line, Group I; dotted line, Group II; broken line, Group III

CHANGES IN AVERAGE WEEKLY CATCH

As explained above, the average size of catch and the average number of deliveries per week are both subject to certain errors. Thus when the fishing is being con-

ducted at a distance the average size of the catch usually will be large and the number of deliveries necessarily will be small. When fishing close to the plant the size of catch may be large or small, but the number of deliveries will usually be higher than when fishing distant grounds. The average total catch per boat per week, therefore, is probably a more trustworthy measure of abundance than either of the foregoing. However, one criticism applies to it that applies to the average size of catch, namely, that the shift in the fishing ground keeps the trend from showing the true decline in abundance, so that all decreases that are shown are minimum.

In studying the average weekly catch per boat the data were treated similarily to those of the average number of deliveries, the average catch per week being assumed to be the average for each day within the week. As with the study of the number of deliveries, all of the weekly averages previous to 1927 were multiplied by the factor 0.786 to allow for the 36-hour weekly closed season of recent years. The results of the computations are given in Table 6.

TABLE 6.—*Comparisons of weekly average catches per boat with a standard catch curve*

Month	Geometric means of the weekly average catches per boat expressed as percentages of the standard curve									Geometric means expressed as percentages of 1928 mean								
	1921	1922	1923	1924	1925	1926	1927	1928	1929	1921	1922	1923	1924	1925	1926	1927	1928	1929
GROUP I																		
June	64.3	99.0	112.0	106.7	124.6	92.3	61.6	84.5	80.2	76.1	117.1	132.6	126.3	147.4	109.2	72.9	100	94.9
July	68.2	83.4	88.8	81.2	59.7	75.8	64.1	99.2	32.5	68.8	84.1	89.6	81.9	60.2	76.4	64.6	100	32.8
August	32.8	61.9	61.3	78.6	120.7	135.9	71.0	64.0	95.2	51.2	96.7	95.8	122.8	188.5	212.2	110.9	100	148.7
September	----	44.1	66.9	54.0	26.6	104.3	84.8	82.5	165.0	----	53.5	81.1	65.5	32.3	126.4	102.8	100	200.0
Total	61.4	87.6	80.6	82.1	102.0	114.3	69.2	81.4	77.5	75.4	107.6	99.8	100.9	125.3	140.4	85.0	100	95.2
Number of boats	2	1	3	2	8	7	19	26	28	----	----	----	----	----	----	----	----	----
Average tonnage	14.0	30.0	24.0	28.5	25.5	30.4	31.7	33.1	33.4	----	----	----	----	----	----	----	----	----
GROUP II																		
June	----	----	----	----	----	83.9	63.9	106.5	122.8	----	----	----	----	----	79.1	60.2	100	115.8
July	----	----	----	----	----	136.0	85.6	82.0	81.4	----	----	----	----	----	165.9	104.4	100	99.3
August	----	----	----	----	----	101.2	60.0	70.1	54.8	----	----	----	----	----	144.4	85.6	100	78.2
September	----	----	----	----	----	----	82.8	46.7	163.1	----	----	----	----	----	----	177.3	100	349.2
Total	----	----	----	----	----	93.7	72.0	73.9	93.9	----	----	----	----	----	126.8	97.4	100	127.1
Number of boats	----	----	----	----	----	23	23	21	18	----	----	----	----	----	----	----	----	----
Average tonnage	----	----	----	----	----	27.8	30.7	34.1	35.2	----	----	----	----	----	----	----	----	----
GROUP III																		
June	----	----	----	221.5	110.3	37.2	43.7	46.7	----	----	----	----	474.3	236.2	79.6	93.6	100	----
July	----	----	----	176.6	144.9	78.6	32.2	41.1	----	----	----	----	429.9	352.7	191.3	78.2	100	----
August	----	----	----	127.0	87.8	110.0	46.5	36.5	----	----	----	----	348.0	240.6	301.4	127.4	100	----
Total	----	----	----	169.6	114.6	69.0	40.1	41.0	----	----	----	----	413.9	279.5	168.3	97.8	100	----
Number of boats	----	----	----	2	2	6	8	7	----	----	----	----	----	----	----	----	----	----
Average tonnage	----	----	----	31.5	30.5	28.0	30.1	32.5	----	----	----	----	----	----	----	----	----	----
ALL BOATS																		
June	----	----	----	----	----	89.6	74.7	105.0	109.8	----	----	----	----	----	85.3	71.1	100	104.5
July	----	----	----	----	----	157.3	82.8	83.8	67.1	----	----	----	----	----	187.7	98.8	100	80.1
August	----	----	----	----	----	116.1	61.7	63.4	85.8	----	----	----	----	----	183.1	97.3	100	135.4
September	----	----	----	----	----	76.7	71.7	57.5	131.6	----	----	----	----	----	133.4	124.7	100	229.0
Total	----	----	----	----	----	106.5	72.3	74.6	94.9	----	----	----	----	----	142.8	96.9	100	127.2
Number of boats	----	----	----	----	----	36	57	65	56	----	----	----	----	----	----	----	----	----
Average tonnage	----	----	----	----	----	28.3	31.1	33.3	33.7	----	----	----	----	----	----	----	----	----

Figure 15 gives the comparisons with the standard curve (fig. 16) for Group I. It will be noted at once that 1921 is low in every case, but this is not believed to indicate necessarily a lack of abundance for two reasons: First, because the two boats for which data are available in 1921 were exceedingly small (Table 6); second, because

1921 was a year in which the herring companies operated on a very restricted scale, owing to poor economic conditions (Rounsefell, 1930, p. 234). Disregarding 1921, June shows a higher level of abundance during the next four years than during the last four. July shows minor variations, but the general trend appears to maintain a level. August is characterized by a very sudden rise in 1925 and as sudden a drop in 1927. September fluctuates considerably but shows a very considerable rise, especially since 1925.

In the combined data it will be noted that whereas the curve for all of the months does not show a decline, the curve for the first three months, June to August, does appear to show a decrease. The reason for the difference between the two curves is the rise in September during the past few years. Although this September rise is undoubtedly valid, in comparing the various years it is better to eliminate the September data, for it is only within the last few years (possibly owing largely to the increase in size and seaworthiness of the fishing vessels) that the September fishing has been very successful. Of former years when autumn approached and no herring were to be had in the more sheltered bays in the lee of Cape Ommaney, the plants suspended operations for the season; but since the fishermen have learned to seine herring in the dangerous tide rips and high ocean swells around Cape Ommaney, the plants usually operate with success until the end of September. The high relative abundance of herring during this final run is indicated by Figure 16, which gives the standard curve for Group I.

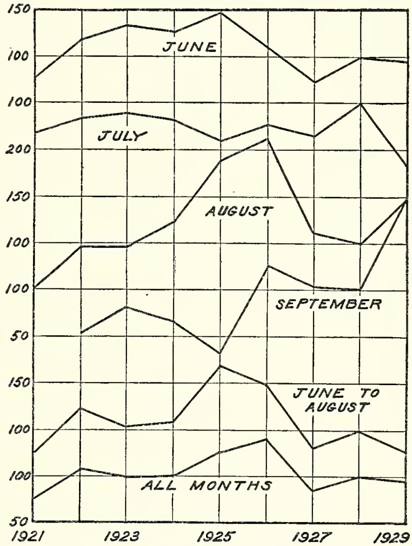

FIGURE 15.—Showing for Group I the geometric means (expressed as percentages of the 1928 mean) of the percentages that the average weekly catch per boat is of a standard curve (see text)

It must be concluded that Group I gives evidence of a slight decline in abundance during the period from June to August. The apparent increase during September is probably due in large part, if not wholly, to the changes in the efficiency of the fleet.

In Group II (figs. 17 and 18) the data cover only the past four years. June shows a considerable rise in 1928 and 1929 over the first two years. In both July and August the year 1926 is quite high, and the last three years are about equal. In September, 1929 is at such a high plane as to indicate great abundance, but this is doubtless due in part to the absence of data during September in 1926, since the high 1929 year is compared to a standard curve considerably lower than would surely be the case were 1926 included.

From the total curve it may be concluded that for Group II, 1926 was a year of greater abundance than 1927 and 1928; 1929 may have been a year of as great abundance as 1926, but this appearance in our curves is probably an artifact owing to lack of data during September, 1926.

In Group III (figs. 19 and 20) the data cover a 5-year period from 1924 to 1928, in-

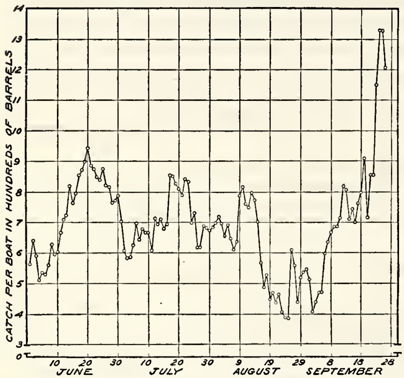

FIGURE 16.—The standard curve for average weekly catch per boat for Group I (see text)

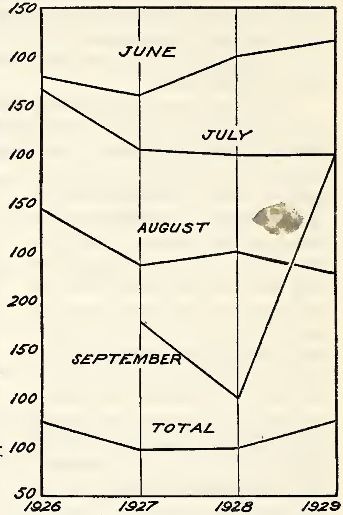

FIGURE 17.—Showing for Group II the geometric means (expressed as percentages of the 1928 mean) of the percentages that the average weekly catch per boat is of a standard curve (see text)

clusive. The decline during all months is so tremendous as to leave no doubts concerning the validity of the decline in abundance and shows good cause why both of the plants in this group discontinued operations at the end of 1928. The only reason that 1928 did not show a further decline over 1927 is that in the latter year these plants extended their operations to distant areas, taking over 50 per cent of their catch in areas 8, 9, and 20. Why this group, alone, of the three under consideration should show such a tremendous decline is perhaps best explained by comparing Figure 20, giving the standard curve for this group, with Figures 16 and 18. Group III, as is shown, depends chiefly on the early portion of the season, taking practically nothing after mid-August, while Groups I and II obtain a very considerable portion of their season's catch after the middle of August. Another reason why Groups I and II have not declined so rapidly as Group III is found in their exploitation during

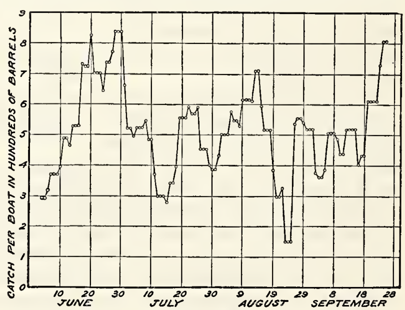

FIGURE 18.—The standard curve for average weekly catch per boat for Group II (see text)

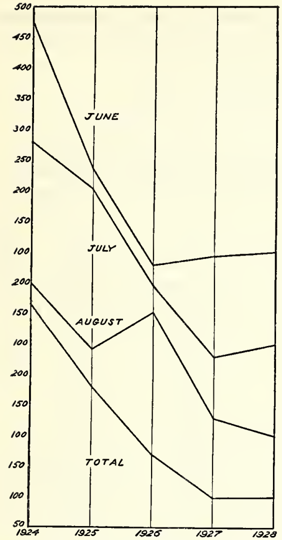

FIGURE 19.—Showing for Group III the geometric means (expressed as percentages of the 1928 mean) of the percentages that the average weekly catch per boat is of a standard curve (see text)

late years of area 6 during the month of June. The reasons for these differences in general trends of abundance will be discussed more fully below.

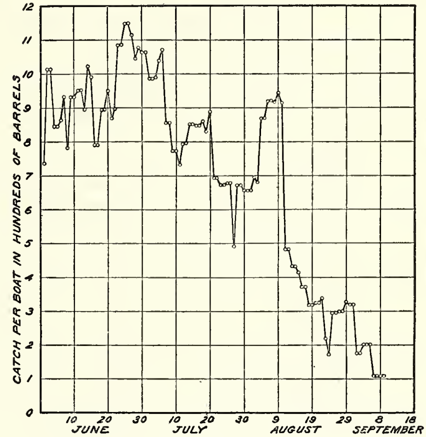

FIGURE 20.—The standard curve for average weekly catch per boat for Group III (see text)

LEVELS OF ABUNDANCE IN DIFFERENT AREAS

An attempt was made to discover whether the general trends of abundance indicated in the foregoing analyses were caused by general changes in the level of abundance in all areas fished or whether each area had its own level of abundance. In determining the abundance in an individual area it is not feasible to use either the catch per boat per week or the number of deliveries, as both depend chiefly on the relative abundance in other areas in which fish are being taken. Resort was made, therefore, to the average size of catch as it is to a larger extent free from the shortcomings of the other methods.

The simple computations involved are presented in Table 7 and Figure 21. Figure 21 reveals the striking fact that the general level of abundance in each area under consideration is in inverse order to the length of time during which it has been subject to exploitation on any scale. Areas 11 and 12 have been exploited since the founding of Killisnoo in 1882, and areas 14

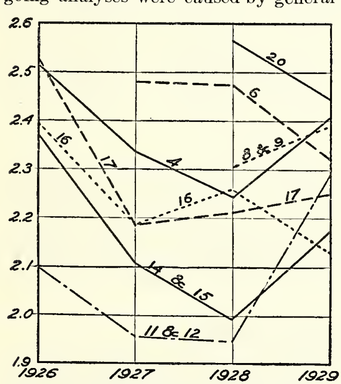

FIGURE 21.—Showing the logarithms of the actual catch (unweighted) in several statistical areas for different years (see fig. 9)

and 15 were early exploited by the same company. Areas 4, 16, and 17 commenced to be intensively exploited about 1917. Area 6 was not fished intensively before 1927. No real effort was made to fish areas 8, 9, and 20 until 1928.

TABLE 7.—*Average size of catches in barrels in individual areas*

Area	Month	1926		1927		1928		1929	
		Average size of catch	Number of catches	Average size of catch	Number of catches	Average size of catch	Number of catches	Average size of catch	Number of catches
4	June	288.4	37	180.4	400	175.9	434	108.4	331
	July	298.1	43	262.2	226	167.9	387	123.3	133
	August	324.0	232	200.4	344	144.0	538	264.6	586
	September	368.3	71	307.0	109	195.3	477	346.9	666
	Total	325.8	383	216.7	1,079	175.7	1,776	255.5	1,776
6	June	-	-	435.5	4	301.7	180	210.3	27
	July	-	-	279.7	23	74.5	2	207.7	6
	August	-	-	-	-	223.0	1	-	-
	Total	-	-	302.8	27	298.8	183	209.8	33
8 and 9	June	-	-	-	-	481.5	2	149.5	2
	July	75.0	2	280.0	1	139.4	8	292.0	25
	August	-	-	197.0	2	193.5	10	137.1	9
	September	-	-	83.0	2	204.0	3	-	-
	Total	75.0	2	168.0	5	201.1	23	245.4	36
11 and 12	June	54.0	3	-	-	162.5	2	-	-
	July	236.0	2	134.8	8	53.9	7	201.8	17
	August	138.3	3	60.5	12	69.9	13	168.3	4
	September	110.0	3	-	-	142.0	6	-	-
	Total	125.4	11	90.2	20	88.0	28	195.4	21
14 and 15	June	203.7	7	-	-	70.0	1	152.9	22
	July	185.6	23	132.6	28	94.7	16	147.6	75
	August	263.5	50	116.8	15	105.1	12	124.5	2
	September	45.0	1	-	-	-	-	-	-
	Total	233.5	81	127.1	43	98.1	29	148.3	99
16	June	182.5	4	166.9	29	226.7	78	95.2	36
	July	467.0	1	103.8	5	147.9	75	228.9	17
	August	261.0	3	17.0	1	128.6	15	127.4	22
	September	-	-	-	-	49.0	1	-	-
	Total	247.5	8	153.6	35	182.0	169	135.0	75
17	June	65.5	2	182.0	22	243.5	2	228.6	364
	July	390.9	10	154.4	182	157.1	129	114.7	252
	August	337.2	90	125.8	29	173.0	53	129.8	25
	September	62.0	1	16.0	1	130.5	2	-	-
	Total	334.5	103	153.4	234	162.3	186	179.9	641
20	June	-	-	-	-	383.0	44	278.7	27
	July	-	-	-	-	359.3	16	294.6	40
	August	-	-	-	-	184.3	3	191.0	8
	Total	-	-	-	-	367.5	63	277.8	75

The conclusion logically follows that the general trends of abundance previously presented do not give the true state of affairs in so far as particular areas are concerned. The fishery has not been confined, and as the abundance in the exploited areas commenced to decline the fishery pushed on to new areas. This process has been going on for so long a time that it can not be adequately shown within the space of a few years. Evidence showing such a shift has been published in a previous report (Rounsefell, 1930, p. 237).

DECLINE OF OLDER FISHING GROUNDS

That there has been an extensive shift in the fishing grounds is certain, but direct evidence bearing on the subject is scant. Moser (1899) mentions the Killisnoo plant operating 3 purse seines, 125 to 150 fathoms long, 12 fathoms deep, and ½-inch-mesh

stretched measure, in the lagoon at Kootznahoo Inlet (area 12). The Reverend Kashevaroff, curator of the Alaska Territorial Museum, told the author in an interview, "In 1894, 1895, and 1896 (when he observed the fishery) Chatham Strait was always full of herring off Danger Point. The Killisnoo fishermen lived at the lagoon and brought about 1,200 barrels of herring daily to the factory at Killisnoo." Capt. Elling Arentsen in 1924 compiled from the log books of the Killisnoo steamers a table giving the amounts taken (in round numbers) and the locations of the catches in various years from 1895 to 1915. His figures for Killisnoo lagoon are given in Table 8.

TABLE 8.—*Catches reported taken by the Killisnoo plant in Killisnoo lagoon in various years from 1895 to 1915*

Year	Catch in barrels	Year	Catch in barrels	Year	Catch in barrels	Year	Catch in barrels
1895	20,000	1900	20,000	1906	10,000	1912	10,000
1896	20,000	1903	15,000	1909	10,000	1913	9,000
1897	20,000	1904	15,000	1910	10,000	1914	8,000
1898	20,000	1905	15,000	1911	12,000	1915	5,000
1899	20,000						

These figures show a considerable decline in abundance in Kootznahoo Inlet. That such a decline has progressed much farther is indicated by the figures for the past four years in which the total catches in barrels for area 12 (which includes Kootznahoo Inlet) for all of the boats in southeastern Alaska were as follows: 1926, 1,379; 1927, 1,202; 1928, 1,475; and 1929, 2,179 barrels. Area 12 would appear to represent a case of extreme depletion.

The limits of the fishing grounds utilized by the Killisnoo plant up to 1911 are clearly defined in the following statement by Carl Spuhn, president of the company then operating Killisnoo (United States Senate, 1912):

The fishing industry in Alaskan waters, whether it takes the form of the business of the salmon packer, the halibut fisher, or is confined to the industry as carried on by our company, must necessarily have some central point to which fish can be carried for preparation for market in any form, and from this central point the fishing must radiate. Necessarily, therefore, the territory covered by the fishermen, particularly in a business which utilizes the herring, is restricted in area. The territory covered by our operations includes a radius of from 40 to 50 miles north and south from Killisnoo, where the plant is located, and it embraces the waters surrounding Admiralty Island. Thus our operations extend up Chatham Strait along the west coast of Admiralty Island approximately as far as Funter Bay, thence across Chatham Strait to Icy Strait, and down the east coast of Chichagof and Baranof Islands to Prince Frederick Sound, and along the easterly coast of Admiralty Island to Seymour Canal. The Alaskan waters in and about Ketchikan, Wrangell, Juneau, Skagway, and Sitka, in southeastern Alaska, are not invaded by the fishing operations of this company, and they are too far distant from the located plant of the company to make possible any fishing by us in those waters.

As shown in a previous report (Rounsefell, 1930, Table 1, p. 237) the Killisnoo plant took 60 per cent of its 1927 catch around Cape Ommaney (area 4) and 53 per cent of its 1928 catch in Lynn Canal (Stephens Passage, area 20). In 1928 they also took 11 per cent from Sitka (area 2). All of these areas were considered too far away from the plant to be profitably fished as late as 1911.

In Seymour Canal (area 21) records are available of fishing as early as 1904. Quoting from Cobb (1906, p. 20):

During the season of 1905 the Alaska Fish & Development Co., of Pleasant Bay, on Glass Peninsula, installed a fertilizer plant aboard a large hulk anchored in the bay, but they were unable

to get it in readiness to operate before the season closed. They put up a considerable quantity of salted herring, however. In 1904 this company operated a trap net for herring in the bay, but it was not set in 1905.

In the summary of Killisnoo catches prepared by Captain Arentsen (mentioned above), 10,000 barrels were taken in Seymour Canal in 1909 and in 1910; 5,000 barrels were taken in 1912 and again in 1913. The Alaska Pacific Herring Co. salted and fished in Seymour Canal in the fall of 1916. Donald R. Crawford (then an employee of the Bureau of Fisheries) says a saltery scow with either two or three seine boats fished in Seymour Canal in 1917. Harold Arentsen reports that Big Port Walter caught 2,700 barrels in 1920 and 1,500 in 1921, in Seymour Canal. These scattered references, however incomplete, indicate that Seymour Canal was a producer of herring for at least 18 years (1904 to 1921). The detailed catch records for every boat from 1926 to 1929 do not show a single catch from this area. Surely this absolute failure is indicative of severe depletion in area 21.

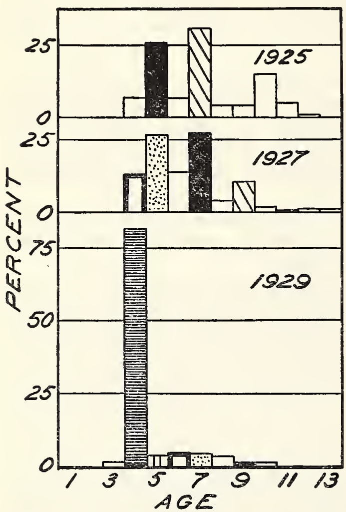

FIGURE 22.—Age histograms for herring from area 14 (Point Gardner) for 1925, 1927, and 1929

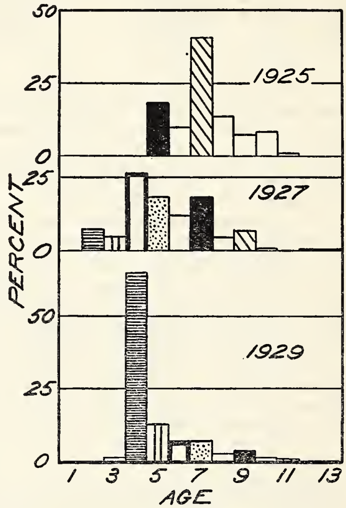

FIGURE 23.—Age histograms for herring from area 17 (Tebenkof Bay) for 1925, 1927, and 1929

BIOLOGICAL EVIDENCE OF DEPLETION

In determining the presence and extent of depletion, decreases in the trends of abundance, as shown above, although testifying to a decline, must be accepted with reservation (especially when the decline covers but a short period of years), unless biological evidence can be brought forth to show that the scarcity of herring is not a temporary phenomenon associated with some feature of the herring's life history, such as dominant year classes. For many of the areas that were once good producers of herring (such as 21, 23, and 24) the decline has been so pronounced that

it has not even been possible to obtain samples of herring from them. In such cases depletion is the only logical verdict.

Unfortunately the staff has been too small in the past to permit of adequate sampling throughout Alaska, so that in the southeastern district, previous to 1929, the only summer samples available are from a few of the areas for the years 1925 and 1927. Comparisons of the ages of the herring taken in these three years in areas 14 and 17 are shown in Figures 22 and 23. (See Table 9.) The passage of dominant year classes is apparent, but not so striking as the falling off of the older age groups in the later years.

TABLE 9.—*Age frequencies for areas 14 and 17*

Age	1925		1927		1929	
	Actual	Per cent	Actual	Per cent	Actual	Per cent
AREA 14						
1	-------	-------	-------	-------	-------	-------
2	-------	-------	-------	-------	-------	-------
3	-------	-------	-------	-------	3	1.5
4	7	7.0	22	12.8	162	81.4
5	26	26.0	46	26.7	7	3.5
6	7	7.0	24	14.0	9	4.5
7	31	31.0	47	27.3	8	4.0
8	4	4.0	7	4.1	6	3.0
9	4	4.0	18	10.5	2	1.0
10	15	15.0	3	1.7	2	1.0
11	5	5.0	1	.6	-------	-------
12	1	1.0	2	1.2	-------	-------
13	-------	-------	2	1.2	-------	-------
Total	100	-------	172	-------	199	-------
AREA 17						
1	-------	-------	-------	-------	-------	-------
2	-------	-------	25	7.4	-------	-------
3	-------	-------	17	5.0	8	1.2
4	-------	-------	89	26.3	447	64.9
5	15	18.5	61	18.0	87	12.6
6	8	9.9	41	12.1	47	6.8
7	33	40.8	61	18.0	47	6.8
8	11	13.6	16	4.7	17	2.5
9	6	7.4	24	7.1	24	3.5
10	7	8.6	2	.6	7	1.0
11	1	1.2	-------	-------	5	.7
12	-------	-------	1	.3	-------	-------
13	-------	-------	1	.3	-------	-------
Total	81	-------	338	-------	689	-------

The relative lack of older age groups in 1929 might be due to either of two causes: (1) To a scarcity of older fish due to depletion, or (2) to an unusual abundance of younger fish. If the latter were true, then the population as a whole should be very numerous; so numerous that the ordinary number of older fish constitutes but a small portion of the stock. This hypothesis needs to be carefully examined. The average percentages of herring above 4 years of age in the two areas in 1925, 1927, and 1929 were 96.5, 72.7, and 25.5, respectively. In 1927 when the proportion of herring over 4 years of age was 72.7, the average size of catch in areas 14, 15, and 17 was 140.3 barrels; in 1929 when the proportion over 4 years of age was 25.5, the average catch in the two areas was 164.1 barrels, or an increase of 17 per cent. If the relative lack of older age groups was entirely caused by the abundance of the 4-year-old group, the catch might have been expected to have increased to an average of 400 barrels or an increase of 185 per cent, assuming in each case the actual numbers of herring over 4 years of age to have remained the same, as $\frac{72.7}{25.5}$ equals $\frac{400}{140.3}$.

Obviously the decline in the relative numbers of older fish as contrasted with younger fish has been caused chiefly by a great decrease in the numbers of older fish, and only in very small part by an increase in abundance of young fish, supporting the previous evidence of considerable overfishing.

CONCLUSIONS

(1) The general trend of abundance, as shown by the boats delivering to the plants south of Point Ellis (Group I) is slowly declining.

(2) The general trend of abundance, as shown by the boats delivering to the plants north of Point Ellis and south of Wilson Cove (Group II), was higher in 1926 than in the three succeeding years, of which 1929 was the best.

(3) The general trend of abundance, as shown by the boats delivering to the plants north of Wilson Cove (Group III), has fallen tremendously and steadily since 1924.

(4) The decrease in abundance in the individual areas is proceeding at a much faster rate than in the general trend, which is held up by the exploitation of new areas.

(5) The areas which have been exploited over a long period of time, for which data are available, as areas 12 and 21, have been depleted to the point of commercial extinction.

(6) The relative numbers of older fish show a very large decrease from 1925 to 1929.

(7) The decrease in relative numbers of older fish has not been caused (except perhaps to a very limited extent) by the influx of dominant year classes of younger fish. This decrease in relative numbers of older fish therefore supports and confirms the previous conclusions that the decreases in abundance are due to depletion.

(8) There are few areas remaining which the fishery is not now exploiting so that the general trend may be expected to continue to fall, perhaps at an accelerated rate, unless some remedial measures are applied.

RECOMMENDATIONS

FUNDAMENTAL CONSIDERATIONS

Certain general principles must be outlined before regulations can be framed to halt the course of depletion that is threatening the commercial extinction of the herring fisheries of southeastern Alaska. A clear picture must be gained of what has occurred.

An intensive fishery was maintained on the older and better known fishing grounds until they no longer produced sufficient raw material. Then the fishery sought new grounds, usually at a greater distance from the plant. If the older grounds had now been entirely abandoned, the situation might not have become so alarming. However, this did not occur. The fishermen continued to seek for herring on the old and well-known fishing grounds long after they had ceased to produce a fair return. In going to and returning from newer and more productive grounds they traversed and fished the older grounds. In periods of stormy weather or seasonal scarcity the older grounds, being nearer to the plants and usually more sheltered than the newer, were fished intensively. As a result of these conditions, each fishing ground, once depleted, remained depleted, without any chance to recover, long after it had ceased to be of any real value to the fishery. Thus it appears that regulations cur-

Figure 24.—Herring reduction plant and saltery at Big Port Walter. The unloading elevator is to the left, next to right is the reduction plant, the next building is the saltery and the one on the right is for storage of nets and equipment. Note the tanks for the storage of herring oil. The machinery in this plant is run wholly by water power, and water can be seen leaving the outlet of the pipe just to the right of the oil tanks. Taken June, 1929

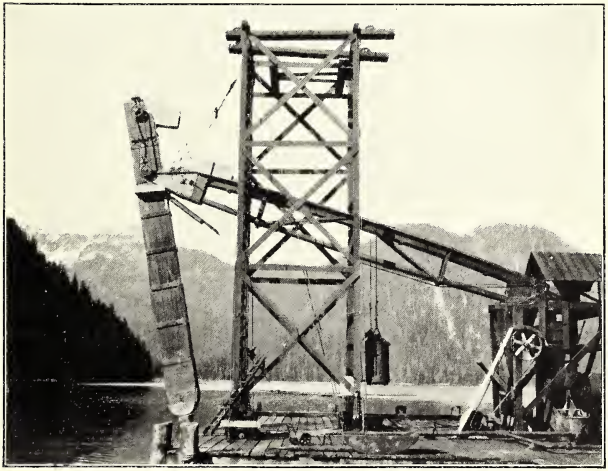

Figure 25.—Close-up of the endless-chain bucket fish elevator shown in Figure 24

tailing the fishing on these older grounds would be of the greatest benefit, since they would permit the rehabilitation of large areas once productive, and, at the same time, would not work a hardship on the present fishery, which obtains but a trifling amount from these depleted grounds.

In addition to the closure of the grounds showing the greatest depletion, a few of the newer grounds should be closed for a part of each season to prevent a repetition of what has occurred before. In selecting the portions of the season to close, attention must be paid to the time at which the herring are taken on each ground so as to prohibit fishing during a portion of this time and not during a time when no fish are expected to be running.

To relieve the newer fishing grounds of the additional strain that will be imposed upon them by the closure of some of the older grounds, it will be well to encourage fishing in a few of the more distant areas not so intensively fished at present.

SPECIFIC RECOMMENDATIONS

(1) That all commercial fishing for herring, including bait fishing, be prohibited for a period of five years in the waters of areas 11, 12, 13, 21, and 23. (See *A* and *B*, fig. 26.)

(2) That all commercial fishing for herring, including bait fishing, be prohibited in areas 14 and 15 (see *C*, fig. 26) except from August 1 to 31, inclusive.

(3) That all commercial fishing for herring, including bait fishing, be prohibited in area 17 (see *D*, fig. 26) during the month of July.

(4) That in areas 3, 4, and 16 (see *E*, fig. 26) the 36-hour weekly closed season be extended to 48 hours, from 12 o'clock noon on Saturday to 12 o'clock noon on Monday.

(5) That all commercial fishing for herring be prohibited in areas 19 and 20 (see *F*, fig. 26) prior to July 1 in each calendar year.

(6) That none of these recommendations shall prohibit the taking of bait by salmon trolling boats with the gear permitted by section 5 of the general regulations. (See Department of Commerce Circular No. 251, Laws and Regulations for Protection of Fisheries of Alaska.)

(7) That recommendations 2, 3, and 5 providing for longer closed seasons in certain areas shall not apply to the taking of herring for bait by boats of not more than 50 feet in length, as shown by official register.

(8) That none of these recommendations shall apply to the commercial use of gill nets of not less than 2¾-inch mesh stretched measure between knots from June 1 to December 31, both dates inclusive.

(9) That the use of herring of over 10½ inches in total length measured from the tip of the snout to the end of the tail fin for reduction purposes be regarded as wanton waste under section 8 of the act of June 26, 1906. Any wilful use or changes of gear, machinery, or handling so as to depreciate the value of herring as food shall be considered as an infringement of this regulation.

EXPLANATION OF SPECIFIC RECOMMENDATIONS

Recommendation 1 prohibiting fishing in areas 11, 12, 13, 21, and 23 (see *A* and *B*, fig. 26) for a period of five years is not as harsh as it might seem. These areas are so depleted that their closure will not curtail the catch more than 1 or 2, possibly as high as 5, per cent. (See Tables 10, 11, and 12.)

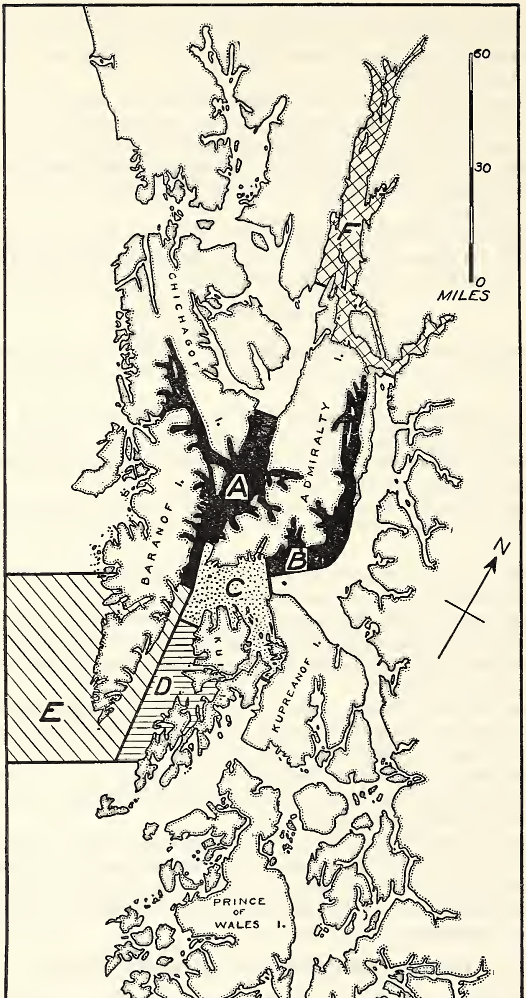

FIGURE 26.—Portion of southeastern Alaska, showing areas for which recommendations were made (see text)

It is hoped that by protecting this tiny remnant of a once numerous population that these areas may again become productive. Five years is entirely arbitrary. One should not entertain too optimistic hopes of restoring these areas to their former abundance in such a short period of time.

Recommendation 2 prohibiting fishing in areas 14 and 15 (see *C*, fig. 26) except during August is believed necessary. Tables 10, 11, and 12 show that entire closure of these areas would have but a trifling effect on the total catch. The proposed regulation would hardly more than halve the catch of these areas as the run occurs in July and August. As against fishing during July, it is felt that August is preferable as insuring a better quality of fish.

Recommendation 3 closing area 17 (see *D*, fig. 26) during July, may, in some years affect the total catch to the extent of 10 per cent. It would be better perhaps from the standpoint of quality of the fish to close this area during June instead of July, but on the other hand it is desirable to allow fishing in area 17 in June to counterbalance recommendation 5.

Recommendation 4 extending the weekly closed season in areas 3, 4, and 16 (see *E*, fig. 26) to 48 hours is chiefly for the purpose of stimulating fishing in distant areas in order to equalize the strain on all areas. It will have but a slight effect on the catch in the areas in question; but, as these areas do not show as pronounced a decline as some of the others, it is not believed expedient to impose a seasonal closed period.

Recommendation 5 extending the opening date in areas 19 and 20 (see *F*, fig. 26) from June 1 to July 1 is imposed for two reasons. One is that this area is subject to a considerable winter bait fishery, and it is felt that the use of herring for halibut bait ranks above its use for reduction. Another reason is that the herring taken in June in this area in the past are reported to be much smaller than those taken in July, and it is desirable to protect these smaller sizes whenever possible.

Recommendation 6 allowing salmon trollers to take small quantities of bait needs no explanation.

Recommendation 7 allowing the taking of bait in all but the permanently closed areas by boats of not over 50 feet official register length, takes cognizance of the fact that the use of herring for bait is of primary importance. Limiting the gear to boats of not more than 50 feet official register length will serve to prevent the large purse seiners of the reduction plants taking herring for reduction under the false plea of bait, and will thus make enforcement comparatively easy.

Recommendation 8 allowing the commercial use of gill nets of not less than 2¾-inch mesh, stretched measure, between knots from June 1 to December 31, both dates inclusive, in all areas, is designed to encourage this type of gear which is the least destructive to the herring population as it does not take the smaller sizes.

Recommendation 9 is especially aimed at stopping the tremendous waste of large fat herring from area 20 that have in the past been used chiefly for reduction.

DEFINITIONS OF AREAS FOR WHICH SPECIFIC RECOMMENDATIONS ARE MADE

Area A.—All waters of Chatham Strait, Peril Strait, and contiguous waters embraced within the following lines: A line running from a point on the west shore of Chatham Strait about 3 nautical miles south of South Passage Point, at 57° 42′ 30″ north latitude, thence easterly, to a point on the eastern shore of Chatham Strait in the vicinity of Marble Bluffs, at 57° 42′ north latitude. A line crossing Peril Strait about one-half nautical mile north of Rapids Point from a point at 57° 27′

30″ north latitude on the west shore, thence easterly, to a point at 57° 27′ 20″ north latitude on the east shore. A line running from a point on the east shore of Chatham Strait about 1¾ nautical miles south of Point Wilson at 57° 6′ 30″ north latitude, westerly 277°, to a point approximately in mid-channel, 2½ nautical miles from the first-mentioned point, thence bearing true south to a point approximately 2½ nautical miles true east from the light at the south entrance to Warm Spring Bay, thence southeasterly to a point 4 nautical miles true east of a point on the west shore of Chatham Strait at 56° 52′ 30″ north latitude, thence true west to the west shore of Chatham Strait at 56° 52′ 30″ north latitude.

Area B.—All waters contained in Seymour Canal, Gambier Bay, Pybus Bay, the adjoining waters of Frederick Sound, and all contiguous waters, within a line from the southernmost point of Point Hugh, at the entrance of Seymour Canal, southerly to the northwesternmost point of land on Acushla Island, thence southwesterly to a point midway between Cape Bendel, on the southeast shore of Frederick Sound, and a point on the northwest shore of Frederick Sound about three-quarters of a nautical mile east of Deepwater Point at 57° 10′ 20″ north latitude and 134° 13′ west longitude, thence northwesterly to the point mentioned on the northwest shore of Frederick Sound.

Area C.—All waters in Frederick Sound, Chatham Strait, Keku Strait, and contiguous waters embraced within the following lines: A line from Cape Bendel, on the southwest shore of Frederick Sound, to a point on the northwest shore of Frederick Sound about three-quarters of a nautical mile east of Deepwater Point at 57° 10′ 20″ north latitude and 134° 13′ west longitude. A line running from a point on the east shore of Chatham Strait about 1¾ nautical miles south of Point Wilson at 57° 6′ 30″ north latitude, westerly 277°, to a point, approximately in mid-channel, 2½ nautical miles from the first-mentioned point, thence bearing true south to a point approximately 2½ nautical miles true east from the light at the south entrance to Warm Spring Bay, thence southeasterly to a point 4 nautical miles true east of a point on the west shore of Chatham Strait at 56° 52′ 30″ north latitude, thence bearing southerly 173° to a point approximately 5½ nautical miles true west of a point on the east shore of Chatham Strait approximately 3 nautical miles north of the north entrance to Washington Bay at 56° 46′ 5″ north latitude, thence true east to the east shore of Chatham Strait. A line crossing Keku Strait, true east and west at 56° 41′ 30″ north latitude.

Area D.—All waters within Chatham Strait, Washington Bay, Bay of Pillars, Tebenkof Bay, Port Malmesbury, and contiguous waters within a line running true west from a point approximately 3 nautical miles north of the north entrance to Washington Bay on the east shore of Chatham Strait at 56° 46′ 5″ north latitude to a point approximately 5½ nautical miles west of said point and on a line bearing southerly 173° from a point 4 nautical miles true east of the west shore of Chatham Strait at 56° 52′ 30″ north latitude, thence bearing southerly 173° to a point approximately 5½ nautical miles south-southwest ½ west from Point Crowley light, thence running north-northeast ½ east to Point Crowley Light.

Area E.—All waters of Chatham Strait and contiguous waters along the east shore and south shore of Baranof Island and the waters of the Pacific Ocean and contiguous waters extending off the west shore of Baranof Island within the following lines: A line running from a point on the west shore of Chatham Strait at 56° 52′ 30″ north latitude to a point 4 nautical miles true east of the point of beginning, thence bearing 173° south to a point approximately 5½ nautical miles south-southwest ½ west from

Point Crowley Light, thence extending indefinitely south-southwest ½ west. A line extending indefinitely south-southwest ½ west from a point on the west shore of Baranof Island at 56° 46′ north latitude.

Area F.—All the waters of Lynn Canal, Stephens Passage, and contiguous waters within the following lines: A line from a point on the west shore of Lynn Canal at 58° 20′ north latitude to a point on the east shore of Lynn Canal at 58° 21′ north latitude. A line from Point Arden Light on the west shore of Stephens Passage to a point of land at approximately 58° 10′ 20″ north latitude on the east shore of Stephens Passage.

TABLE 10.—*Percentage of herring caught in each area each week by boats of Group I*

[Catches delivered to plants south of Point Ellis, Chatham Strait]

Week ending—	Areas: 3	4	5	6	8	9	11	12	14	15	16	17	20	?	Actual number of barrels caught	Per cent of season's catch	Boats fishing	Per cent of season's catch taken by each boat	Per cent of season's catch weighted by number of boats fishing
1926																	*Number*		
June 6		100.0													620	0.8	2	0.400	1.6
June 13		100.0													1,410	1.7	2	.850	3.4
June 20		100.0													3,607	4.4	2	2.200	8.7
June 27		100.0													2,647	3.2	2	1.600	6.4
July 4		100.0													1,123	1.4	2	.700	2.8
July 11		100.0													2,079	2.5	2	1.250	5.0
July 18		100.0													4,507	5.5	2	2.750	10.9
July 25		100.0													3,952	4.8	2	2.400	9.5
Aug. 1		100.0													2,033	2.5	3	.833	3.3
Aug. 8		62.5										37.5			6,277	7.6	7	1.086	4.3
Aug. 15		95.8										4.2			17,267	21.0	7	3.000	11.9
Aug. 22		100.0													7,536	9.2	7	1.314	5.2
Aug. 29		100.0													3,033	3.7	6	.617	2.4
Sept. 5		100.0													4,107	5.0	6	.833	3.3
Sept. 12		100.0													11,663	14.2	6	2.367	9.4
Sept. 19		100.0													9,066	11.0	5	2.200	8.7
Sept. 26		100.0													663	.8	2	.400	1.6
Sept. 30		100.0													652	.8	2	.400	1.6
1927																			
June 5		74.4									25.5				3,323	2.2	17	.129	2.0
June 12		90.5									3.6			5.9	8,676	5.8	18	.322	5.0
June 19	10.3	86.3												3.4	4,386	2.9	18	.162	2.5
June 26	14.4	76.0										0.9		8.6	14,049	9.4	19	.495	7.7
July 3		79.0		17.1								1.6		2.4	14,023	9.4	19	.495	7.7
July 10		77.0		14.5			3.6							4.9	15,271	10.2	19	.537	8.4
July 17		25.3		60.0					3.2			11.0		.4	5,404	3.6	19	.189	2.9
July 24		12.3								2.5		76.8		7.8	5,629	3.8	19	.200	3.1
July 31		.8	4.8									81.6		12.9	9,025	6.0	19	.316	4.9
Aug. 7		94.1										2.6		3.3	17,200	11.5	19	.606	9.4
Aug. 14		90.0												10.0	13,775	9.2	19	.484	7.5
Aug. 21		68.5										8.0		23.5	3,027	2.0	19	.105	1.6
Aug. 28		91.2									.3			8.5	6,355	4.2	17	.247	3.8
Sept. 4		100.0													2,500	1.7	12	.146	2.3
Sept. 11		100.0													2,294	1.5	10	.150	2.3
Sept. 18		100.0													9,545	6.4	9	.711	11.1
Sept. 25		100.0													15,312	10.2	9	1.133	17.6
1928																			
June 3											100.0				150	.1	26	.004	.1
June 10		79.5		17.9							2.5				6,736	2.8	26	.108	2.6
June 17		23.3		70.4							6.4				17,400	7.3	26	.281	6.8
June 24	.5	51.0		39.5							8.9				22,446	9.4	26	.362	8.7
July 1		64.1		5.2							30.8				28,815	12.1	26	.466	11.2
July 8		72.3		.2							27.5				15,185	6.4	26	.246	5.9
July 15	2.0	88.8							2.8		5.3	1.1			3,758	1.6	26	.062	1.5

July 22		61.3									20.7	18.0			15,713	6.6	26	.254	6.1
July 29		81.8									5.0	13.2			12,031	5.1	26	.196	4.7
Aug. 5		98.7									1.3				12,361	5.2	26	.200	4.8
Aug. 12		83.4							14.7		1.9				2,186	.9	26	.035	.8
Aug. 19		90.8										9.2			18,605	7.8	26	.300	7.2
Aug. 26		100.0													13,648	5.7	26	.219	5.3
Sept. 2		91.3									8.7				14,062	5.9	24	.246	5.9
Sept. 9		100.0													12,562	5.3	22	.241	5.8
Sept. 16		100.0													6,794	2.8	19	.147	3.5
Sept. 23		100.0													16,547	7.0	19	.369	8.9
Sept. 30		100.0													18,807	7.9	19	.416	10.0
1929																			
June 2	2.8	61.5									35.7				608	.2	28	.007	.2
June 9		87.6	2.6	1.4							3.2	1.7	3.5		9,453	2.6	28	.093	2.5
June 16		72.5	15.2	4.8							1.7	3.1	2.7		11,636	3.2	28	.114	3.1
June 23		11.1	28.3	1.0								59.6			27,011	7.4	28	.264	7.2
June 30		12.0	13.4	1.6								72.9			24,739	6.8	28	.243	6.6
July 7		3.6	.8								5.2	90.4			3,230	.9	28	.032	.9
July 14		63.1	3.1	.4				3.4	7.1			22.9			12,315	3.4	28	.121	3.3
July 21		24.8						3.1	7.4			64.8			1,990	.5	28	.018	.5
July 28		18.9			0.6	8.1	.6				18.8	50.4	2.6		14,948	4.1	28	.146	4.0
Aug. 4		57.8				6.8		1.3			6.6	27.6			13,395	3.7	28	.132	3.6
Aug. 11		97.3									2.5	.2			22,268	6.1	27	.226	6.2
Aug. 18		99.2				.8									19,906	5.4	27	.200	5.5
Aug. 25		100.0													2,861	.8	27	.030	.8
Sept. 1		100.0													50,884	13.9	27	.515	14.1
Sept. 8		100.0													28,431	7.8	27	.289	7.9
Sept. 15		100.0													32,492	8.9	27	.330	9.0
Sept. 22		100.0													23,922	6.5	27	.241	6.6
Sept. 29		100.0													63,846	17.5	27	.648	17.7
Sept. 30		100.0													1,638	.4	27	.015	.4
TOTAL																			
1926		96.3										3.7			82,242				
1927	1.7	77.4	.3	5.2			.4		.1	.1	.8	8.9		5.2	149,794				
1928	.1	77.9		10.0					.2		9.2	2.6			237,806				
1929		78.6	3.7	.4		.6		.2	.3		1.4	14.5	.3		365,573				
TOTAL, WEIGHTED BY BOATS FISHING																			
1926		97.9										2.1							
1927	1.4	81.2	.2	4.3			.3		.1	.1	.7	7.3		4.3					
1928	.1	79.3		9.3					.2		8.6	2.4							
1929		79.2	3.6	.4		.6		.2	.3		1.4	14.2	.3						

TABLE 11.—*Percentage of herring caught in each area each week by boats of Group II*

[Catches delivered to plants north of Point Ellis and south of Wilson Cove]

Week ending—	Areas																	Actual number of barrels caught	Percent of season's catch	Boats fishing	Percent of season's catch taken by each boat	Per cent of season's catch weighted by number of boats fishing
	2	3	4	5	6	8	11	12	13	14	15	16	17	18	20	30	Chatham Strait	?					
1926																					*Number*		
June 13			96.8														3.2		1,346	1.6	2	0.800	7.0
June 20																	100.0		3,048	3.6	3	1.200	10.4
June 27																	100.0		1,124	1.3	3	.433	3.8
July 4																	100.0		2,156	2.5	3	.833	7.2
July 11																	100.0		2,598	3.0	3	1.000	8.7
July 18																	100.0		1,555	1.8	3	.600	5.2
July 25																	100.0		4,020	4.7	3	1.567	13.6
Aug. 1			10.0										26.5				63.5		3,837	4.5	6	.750	6.5
Aug. 8			23.1							1.7	2.1		48.0				20.6	4.5	19,701	23.0	20	1.150	10.0
Aug. 15			51.3							4.3	1.1	3.2	33.7				4.6	1.8	24,403	28.4	17	1.671	14.5
Aug. 22			79.8										19.7				.6		18,897	22.0	18	1.222	10.6
Aug. 29			97.4														2.6		3,029	3.5	19	.184	1.6
Sept. 5			100.0																50	.1	1	.100	.9
1927																							
June 5			52.6									42.4					5.1		3,184	2.8	22	.127	2.0
June 12		4.8	58.9									21.2					14.0	1.0	6,916	6.2	23	.270	4.3
June 19			81.8														18.2		4,435	3.9	23	.170	2.7
June 26		4.1	75.0									.2	8.8				12.0		13,686	12.2	23	.530	8.5
July 3			64.0									2.1	12.0	3.0			18.9		16,740	14.9	23	.648	10.4
July 10			82.7							.4							16.5	.3	14,245	12.7	23	.552	8.9
July 17			34.2	4.6	7.3					7.8		3.7	23.3				19.2		3,584	3.2	22	.145	2.3
July 24			17.1										58.2				24.8		7,821	7.0	21	.333	5.3
July 31													79.0				21.0		9,147	8.1	20	.405	6.5
Aug. 7			72.2										19.6				8.1		11,537	10.3	18	.572	9.2
Aug. 14			82.0							.2			2.5				15.3		10,311	9.2	18	.511	8.2
Aug. 21			93.2														6.8		1,670	1.5	17	.088	1.4
Aug. 28			86.2														13.8		2,825	2.5	14	.179	2.9
Sept. 4			35.1			15.1											35.6	14.1	1,024	.9	7	.130	2.1
Sept. 11			99.3			.7													1,565	1.4	6	.233	3.7
Sept. 18			98.9										1.1						1,503	1.3	3	.433	7.0
Sept. 25			100.0																2,066	1.8	2	.900	14.5
1928																							
June 3			12.9									87.1							310	.2	21	.010	.2
June 10			82.1		4.0							13.9							6,332	4.5	21	.214	4.3
June 17			21.6		66.6				2.1				3.1			3.7		2.9	14,231	10.0	21	.476	9.6
June 24			44.2		44.5										10.2	1.1			13,661	9.6	21	.457	9.2
July 1			53.0		16.6					.3		16.3			13.9				21,525	15.1	21	.719	14.5
July 8			73.1							10.0		14.0			2.9				9,673	6.8	21	.324	6.5
July 15			53.7		2.8					6.8		10.8	25.9						4,487	3.2	21	.152	3.1
July 22			27.1									7.6	65.3						9,859	6.9	21	.329	6.6
July 29	0.6		42.2							.7		1.5	55.0						7,781	5.5	21	.262	5.3
Aug. 5			78.0									2.7	19.4						6,679	4.7	21	.224	4.5
Aug. 12			41.6							.7	14.2	2.9	40.8						3,925	2.8	20	.140	2.8
Aug. 19			52.1	2.3	2.0					1.6			42.1						11,351	8.0	19	.421	8.5
Aug. 26			99.7										.3						5,009	3.5	19	.184	3.7

Sept. 2			99.8										.2						6,556	4.6	19	.242	4.9
Sept. 9			100.0																5,434	3.8	19	.200	4.0
Sept. 16			100.0																2,586	1.8	18	.100	2.0
Sept. 23			100.0																4,257	3.0	18	.167	3.4
Sept. 30			97.1										2.9						8,415	5.9	18	.328	6.6
1929																							
June 2			27.1									26.8	13.4		32.7				358	.2	18	.011	.2
June 9			30.9		1.6							21.2	17.5		28.9				6,295	3.9	18	.217	3.2
June 16			18.5		11.1						5.9	3.5	37.8		23.2				7,971	4.9	18	.272	4.0
June 23			3.1		8.0				1.8		3.1	3.1	74.0		6.9				22,710	14.1	18	.783	11.5
June 30			2.1							4.3	7.4		86.2						18,687	11.6	18	.644	9.4
July 7			3.1				9.6			5.5	20.8		48.9		12.1				5,853	3.6	18	.200	2.9
July 14					1.2	6.2	4.3			16.0	15.1	3.5	35.0		18.6				7,470	4.6	18	.256	3.8
July 21			1.7		18.6					2.0	1.8	1.0	1.6		73.1				5,948	3.7	18	.206	3.0
July 28			7.6			18.9		6.5		.5	2.4	4.7	12.3		47.0				8,582	5.3	18	.294	4.3
Aug. 4			33.6			10.9		14.9		.2	5.3		19.4		15.8				4,517	2.8	17	.165	2.4
Aug. 11			66.9									3.9	14.6		14.6				6,839	4.2	12	.350	5.1
Aug. 18			85.4			2.3		4.6							7.7				6,606	4.1	12	.342	5.0
Aug. 25			100.0																118	.1	12	.008	.1
Sept. 1			100.0																18,486	11.5	12	.958	14.0
Sept. 8			100.0																11,603	7.2	12	.600	8.8
Sept. 15			100.0																10,920	6.8	12	.567	8.3
Sept. 22			100.0																6,732	4.2	12	.350	5.1
Sept. 29			100.0																11,049	6.9	12	.575	8.4
Sept. 30			100.0																373	.2	12	.017	.2
TOTAL																							
1926			42.9							1.6	.8	.9	26.1				26.1	1.5	85,764				
1927		.8	63.2	.1	.2	.1				.3		3.0	16.4	.4			15.2	.2	112,259				
1928			60.5	.2	13.9				.2	1.1	.4	5.4	14.3		3.3	.5		.3	142,071				
1929			47.5		2.5	1.7	.5	1.0	.3	1.6	3.4	2.1	28.3		11.2				161,117				
TOTAL, WEIGHTED BY BOATS FISHING																							
1926			28.1							.8	.4	.5	13.5				56.1	.7					
1927		.6	70.9	.1	.2	.3				.2		2.1	12.8	.3			12.0	.4					
1928			61.3	.2	13.3				.2	1.1	.4	5.2	14.1		3.1	.5		.3					
1929			56.2		2.0	1.4	.4	.9	.2	1.3	2.7	1.8	23.2		9.5								

TABLE 12.—*Percentage of herring caught in each area each week by boats of Group III*

[Catches delivered to plants north of Wilson Cove]

Week ending—	Areas																	Actual number of barrels caught	Per cent of season's catch	Boats fishing	Per cent of season's catch taken by each boat	Per cent of season's catch weighted by number of boats fishing
	1	2	3	4	6	8	9	11	12	14	15	16	17	20	23	Chatham Strait	?					
1926																				*Number*		
June 6																	100.0	151	0.3	3	0.100	0.4
June 13				39.6					10.7								49.7	1,508	3.2	3	1.067	4.7
June 20				12.2							9.0	9.3					69.6	3,990	8.5	3	2.833	12.5
June 27										16.2	22.1	15.0	4.6				42.2	2,402	5.1	3	1.700	7.5
July 4						4.5	9.0			2.7	13.5		2.1				68.5	1,114	2.4	3	.800	3.5
July 11										9.1	22.1		21.8				47.2	2,086	4.4	3	1.467	6.5
July 18										25.9	20.4						53.7	3,270	6.9	3	2.300	10.1
July 25										26.2		17.2	20.2				36.4	2,713	5.7	3	1.900	8.4
Aug. 1									8.7	31.4	6.1		53.8					5,403	11.4	6	1.900	8.4
Aug. 8									1.5	79.7	4.1		10.9			3.8		8,067	17.1	7	2.444	10.8
Aug. 15	4.6			36.4					3.6	17.2			38.2					7,978	16.9	6	2.817	12.4
Aug. 22				69.0						22.2			8.7					6,294	13.3	6	2.217	9.8
Aug. 29				26.5						54.8			18.6					1,694	3.6	6	.600	2.6
Sept. 5									60.5	8.8			30.7					512	1.1	2	.550	2.4
Sept. 12									100.0									20		1		
1927																						
June 5				100.0														1,679	7.8	6	1.300	7.4
June 12				90.6								9.4						3,190	14.7	6	2.450	14.0
June 19				100.0														1,495	6.9	6	1.150	6.6
June 26				89.5								10.5						3,258	15.0	6	2.500	14.2
July 3				78.2									21.8					1,992	9.2	6	1.533	8.7
July 10				91.6						8.4								2,306	10.7	6	1.783	10.2
July 17				47.5	5.6					38.8		3.2	4.8					1,052	4.9	6	.817	4.7
July 24				9.4					6.5	79.0			5.1					1,326	6.1	6	1.017	5.8
July 31									30.6	48.2			21.2					1,473	6.8	6	1.133	6.5
Aug. 7				13.2						66.0	6.2		14.6					1,516	7.0	6	1.167	6.6
Aug. 14				41.6					28.0	30.4								1,164	5.4	5	1.080	6.2
Aug. 21				3.1		40.9		11.0	14.7	30.2								543	2.5	4	.625	3.6
Aug. 28			14.5			26.5			40.1	18.8								648	3.0	3	1.000	5.7
1928																						
June 3												100.0						98	.3	7	.043	.3
June 10				39.0				15.4				24.1			21.5			1,230	3.9	7	.557	3.6
June 17				86.9										13.1				1,973	6.2	7	.886	5.7
June 24				21.3	5.1									73.7				5,572	17.6	7	2.514	16.0
July 1								1.7						98.3				7,781	24.5	7	3.500	22.3
July 8								2.2	1.4					96.5				5,051	15.9	7	2.257	14.4
July 15	45.3	48.1				6.0				.6								1,847	5.8	6	.967	6.2
July 22	3.0	51.2				45.0			.7									1,763	5.6	6	.933	6.0
July 29		59.0				21.9			19.1									962	3.0	5	.600	3.8
Aug. 5		41.5					31.9		8.9	17.7								583	1.8	5	.360	2.3
Aug. 12						62.0		7.8	1.5	4.0				24.7				1,837	5.8	5	1.160	7.4
Aug. 19		14.1				26.4		24.1	18.5					16.8				588	1.9	5	.380	2.4
Aug. 26						35.3		15.7	49.0									674	2.1	5	.420	2.7

Sept. 2						51.8			48.2									742	2.3	5	.460	2.9
Sept. 9				6.1		44.5		16.2	33.2									1,000	3.2	5	.640	4.1
TOTAL																						
1926	.8			18.6		.1	.2		2.9	29.7	6.0	2.5	19.0			.7	19.4	47,202				
1927			.4	64.6	.3	1.8		.3	5.6	18.5	.4	3.1	5.0					21,642				
1928	2.8	8.5		10.9	.9	11.0	.6	3.1	4.7	.6		1.2		55.0	.8			31,701				
TOTAL, WEIGHTED BY BOATS FISHING																						
1926	.6			15.4		.2	.3		3.3	23.9	7.7	3.7	16.0			.4	28.5					
1927			.8	61.9	.3	3.0		.4	6.9	18.8	.4	3.0	4.8									
1928	3.0	9.6		10.0	.8	13.4	.7	3.5	5.8	.7		1.2		50.6	.8							

TABLE 13.—*Daily catches of herring from 1926 to 1929, inclusive, by boats of Group I and Group II*

BOATS OF GROUP I

[Catches delivered south of Point Ellis]

Day	1926			1927			1928			1929			Average delivery for four years unweighted	Average delivery for four years smoothed by threes
	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery		
	Number	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Barrels*	*Barrels*
June 1				771	3	257.00	43	1	43.00	608	15	40.53	146.84	
June 2				108	1	108.00	107	2	53.50				80.75	168.58
June 3				1,511	7	216.29				310	1	310.00	278.15	158.49
June 4				930	7	132.86				2,406	24	100.25	116.56	159.53
June 5	34	1	34.00				738	6	123.00	1,988	21	94.67	83.89	107.28
June 6	586	2	293.00	18	1	18.00	111	2	55.50	2,620	22	119.09	121.40	98.17
June 7				900	11	81.82	1,590	14	113.57	940	13	72.31	89.23	101.36
June 8	55	2	27.50	1,927	12	160.58	2,544	17	149.65	830	23	36.09	93.46	135.09
June 9	294	1	294.00	1,376	9	152.89	1,716	15	114.40	329	1	329.00	222.57	131.68
June 10	206	2	103.00	1,575	10	157.50	37	2	18.50	37	1	37.00	79.00	147.65
June 11				2,813	14	200.93	121	2	60.50	2,441	15	162.73	141.39	114.18
June 12	23	1	23.00	67	1	67.00	4,569	14	326.36	1,661	23	72.22	122.15	174.69
June 13	832	2	416.00	13	1	13.00	3,940	8	492.50	2,050	17	120.59	260.52	202.34
June 14	416	1	416.00				2,057	16	128.56	3,083	24	128.46	224.34	232.06
June 15	478	1	478.00	322	5	64.40	2,185	10	218.50	2,364	28	84.43	211.33	218.96
June 16	732	2	366.00	308	6	51.33	4,434	18	246.33				221.22	187.12
June 17	359	2	179.50	929	7	132.71	94	1	94.00	436	4	109.00	128.80	220.74
June 18	862	2	431.00	2,730	15	182.00	2,438	5	487.60	2,965	20	148.25	312.21	201.22
June 19	64	1	64.00	84	1	84.00	4,137	16	258.56	3,660	15	244.00	162.64	242.89
June 20	696	2	348.00	120	1	120.00	5,560	22	252.73	6,480	22	294.55	253.82	235.88
June 21	934	2	467.00	2,534	12	211.17	5,044	23	219.30	5,880	22	267.27	291.19	263.39
June 22	531	2	265.50	2,839	11	258.09	2,652	13	204.00	7,590	30	253.00	245.15	259.92
June 23	360	1	360.00	2,635	11	239.55	2,615	20	130.75				243.43	238.26
June 24	518	2	259.00	3,019	14	215.64				3,876	19	204.00	226.21	243.42
June 25	290	1	290.00	2,902	14	207.29	334	1	334.00	4,646	22	211.18	260.62	221.17
June 26							3,748	17	220.47	1,993	15	132.87	176.67	197.78
June 27	14	1	14.00				5,533	20	276.65	3,905	22	177.50	156.05	180.93
June 28				86	1	86.00	8,857	23	385.09	3,979	25	159.16	210.08	200.04
June 29				462	3	154.00	6,257	19	329.32	6,340	29	218.62	233.98	236.86
June 30				4,620	13	355.38	4,086	23	117.65				266.52	218.68
July 1	96	2	48.00	3,887	14	277.64				282	2	141.00	155.55	219.23
July 2	350	1	350.00	4,968	18	276.00	1,530	7	218.57	1,861	19	97.95	235.63	183.55
July 3	297	2	148.50				6,745	25	269.80	421	7	60.14	159.48	212.75
July 4	380	1	380.00	779	2	389.50	2,347	13	180.54	45	2	22.50	243.14	199.16
July 5				5,859	16	366.19	3,048	19	160.42	174	3	58.00	194.87	202.07
July 6	168	1	168.00	7,639	20	381.95	391	5	78.20	447	10	44.70	168.21	168.79
July 7				756	6	126.00	1,124	7	160.57				143.29	152.43
July 8	266	1	266.00	200	6	33.33				138	1	138.00	145.78	139.62
July 9	190	1	190.00	38	2	19.00				2,345	13	180.38	129.79	186.78
July 10	614	1	614.00				1,344	11	122.18	2,245	19	118.16	284.78	199.04
July 11	841	2	420.50				283	7	40.43	1,647	19	86.68	182.54	203.70
July 12				873	6	145.50	405	3	135.00	4,073	27	150.85	143.78	178.90
July 13	805	2	402.50	1,717	7	245.29	270	3	90.00	1,867	18	103.72	210.38	178.18
July 14	160	1	160.00	1,792	9	199.11	1,456	8	182.00				180.37	203.05
July 15	1,408	3	469.33	822	5	164.40				43	2	21.50	218.41	194.95
July 16	1,069	3	356.33	142	2	71.00	2,260	8	282.50	69	2	34.50	186.08	201.90
July 17	491	1	491.00	58	1	58.00	4,597	20	229.85	52	2	26.00	201.21	190.65

July 18	574	2	287.00	137	1	137.00	3,151	16	196.94	824	7	117.71	184.66	189.13
July 19	686	2	343.00	296	4	74.00	3,080	15	205.33	415	4	103.75	181.52	217.42
July 20	507	1	507.00	617	6	102.83	1,612	14	115.14	587	14	419.29	286.07	220.66
July 21	288	1	288.00	1,163	6	193.83	1,013	10	101.30				194.38	226.69
July 22	518	2	259.00	1,315	8	164.38				351	2	175.50	199.63	211.12
July 23	804	3	268.00	2,101	12	175.08	1,609	9	178.78	671	2	335.50	239.34	196.88
July 24	830	2	415.00				2,429	16	151.81	4,517	24	188.21	251.67	219.47
July 25	319	2	159.50	239	2	119.50	4,728	21	225.14	2,482	15	165.47	167.40	200.11
July 26				577	3	192.33	683	7	97.57	6,348	25	253.92	181.27	156.73
July 27	136	2	68.00	4,987	18	277.06	1,030	15	68.67	579	8	72.38	121.53	150.89
July 28	537	2	268.50	858	8	107.25	1,552	21	73.90				149.88	133.61
July 29				1,205	8	150.63				1,515	14	108.21	129.42	132.51
July 30	48	1	48.00	1,159	14	82.79	2,970	14	212.14	2,346	18	130.33	118.32	157.59
July 31	438	1	438.00				3,444	23	149.74	1,136	13	87.38	225.04	173.87
Aug. 1	874	4	218.50				2,825	22	128.41	3,756	20	187.80	178.24	179.03
Aug. 2	521	3	173.67	1,924	10	192.40	1,361	19	71.63	1,560	16	97.50	133.80	157.26
Aug. 3	1,366	5	273.20	283	3	94.33	873	7	124.71	3,082	21	146.76	159.75	141.71
Aug. 4	196	5	39.20	4,500	15	300.00	888	16	55.50				131.57	160.56
Aug. 5	1,023	5	204.60	4,949	17	291.12				678	9	75.33	190.35	199.01
Aug. 6	1,012	5	202.40	5,544	18	308.00				8,504	27	314.96	275.12	220.90
Aug. 7	780	2	390.00				41	1	41.00	3,696	23	160.70	197.23	210.52
Aug. 8	1,379	6	229.83	148	1	148.00	388	10	38.80	5,504	25	220.16	159.20	200.33
Aug. 9	2,817	6	469.50	4,402	16	175.13	650	5	130.00	1,450	14	103.57	244.55	202.86
Aug. 10	3,717	8	464.63	2,342	11	212.91	20	1	20.00	2,436	20	121.80	204.84	239.66
Aug. 11	2,113	6	352.17	979	10	97.90	1,076	3	358.67				269.58	235.51
Aug. 12	2,255	5	451.00	3,749	16	234.31	11	1	11.00				232.10	254.23
Aug. 13	1,536	4	384.00	2,155	10	215.50	543	2	271.50	3,981	23	173.09	261.02	277.13
Aug. 14	3,073	6	512.17				2,449	13	188.38	7,857	25	314.28	338.28	271.43
Aug. 15	1,756	5	351.20				3,839	23	166.91	1,142	9	126.89	215.00	269.11
Aug. 16	2,006	4	501.50	752	4	188.00	2,073	18	115.17	3,807	18	211.50	254.04	221.11
Aug. 17	1,845	5	369.00	747	6	124.50	1,502	15	100.13	3,119	17	183.47	194.28	238.80
Aug. 18	2,334	5	466.80	1,444	15	96.27	8,199	34	241.15				268.07	164.12
Aug. 19				30	1	30.00							30.00	130.56
Aug. 20	967	5	193.40	54	2	27.00				302	5	60.40	93.60	101.32
Aug. 21	384	1	384.00				3,213	22	146.05	11	1	11.00	180.35	117.65
Aug. 22							632	8	79.00				79:00	163.46
Aug. 23	887	4	221.75	2,906	14	207.57	3,311	20	165.55	1,646	5	329.20	231.02	145.23
Aug. 24	254	2	127.00	1,065	10	106.50	790	8	98.75	902	5	180.40	125.66	209.01
Aug. 25	526	1	526.00	1,093	10	109.30	5,624	32	175.75				270.35	153.56
Aug. 26	218	2	109.00	46	1	46.00	78	2	39.00				64.67	172.65
Aug. 27	952	5	190.40	1,245	10	124.50				3,041	13	233.92	182.94	167.63
Aug. 28	104	2	52.00				4,694	22	213.36	12,511	25	500.44	255.27	221.51
Aug. 29	92	2	46.00				928	7	132.57	9,507	19	500.37	226.31	202.04
Aug. 30				1,166	8	145.75	3,844	22	174.73	13,814	26	53.13	124.54	135.29
Aug. 31				59	3	19.67	1,241	13	95.46	11,975	24	49.90	55.01	88.91
Sept. 1				274	3	91.33	3,355	25	134.20	36	1	36.00	87.18	87.76
Sept. 2	42	1	42.00	673	4	168.25				153	1	153.00	121.08	112.19
Sept. 3				328	7	46.86				2,307	11	209.73	128.30	177.88
Sept. 4	1,082	2	541.00				4,372	20	218.60	839	9	93.22	284.27	233.58
Sept. 5	2,983	6	497.17				490	6	81.67	7,142	25	285.68	288.17	274.31
Sept. 6	1,374	4	343.50	1,603	6	267.17	3,230	20	161.50	5,056	22	229.82	250.50	263.39
Sept. 7	1,302	4	325.50	676	7	96.57	1,171	11	106.45	12,415	26	477.50	251.51	240.99
Sept. 8	2,614	6	435.67	15	1	15.00	3,299	19	173.63	519	2	259.50	220.95	280.95
Sept. 9	1,557	4	389.25							2,812	8	351.50	370.38	344.77
Sept. 10	2,236	5	447.20							11,846	27	438.74	442.97	378.33
Sept. 11	1,568	4	392.00				4,074	15	271.60	6,931	23	301.35	321.65	381.59
Sept. 12	1,012	3	337.33							9,728	23	422.96	380.15	282.63
Sept. 13	1,613	5	322.60	302	3	100.67				15	1	15.00	146.09	317.46
Sept. 14	2,051	4	512.75	3,411	9	379.00				1,160	3	386.67	426.14	349.08
Sept. 15	780	2	390.00				2,720	17	160.00				275.00	353.21
Sept. 16	362	1	362.00	2,840	8	355.00							358.50	310.63
Sept. 17	1,643	5	328.60	2,992	9	332.44	43	1	43.00	12,728	26	489.54	298.40	292.67
Sept. 18	1,900	5	380.00				2,322	11	211.09	1,301	18	72.28	221.12	269.31
Sept. 19	717	2	358.50							3,930	18	218.33	288.42	251.96

TABLE 13.—*Daily catches of herring from 1926 to 1929, inclusive, by boats of Group I and Group II*—Continued

BOATS OF GROUP I—Continued

Day	1926 Barrels caught	1926 Deliveries	1926 Average delivery	1927 Barrels caught	1927 Deliveries	1927 Average delivery	1928 Barrels caught	1928 Deliveries	1928 Average delivery	1929 Barrels caught	1929 Deliveries	1929 Average delivery	Average delivery for four years unweighted	Average delivery for four years smoothed by threes
	Number	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Barrels*	*Barrels*
Sept. 20	308	2	154.00	4,242	9	471.33				2,615	23	113.70	246.34	301.50
Sept. 21				4,580	9	508.89	6,530	14	466.43	3,348	25	133.92	269.75	323.05
Sept. 22				1,595	7	227.86	7,652	16	478.25				353.06	341.85
Sept. 23	312	1	312.00	4,202	8	525.25				71	1	71.00	302.75	336.62
Sept. 24				693	3	231.00				13,835	29	477.07	354.04	376.77
Sept. 25							6,616	15	441.07	14,167	28	505.96	473.52	386.00
Sept. 26	43	1	43.00				5,321	12	443.42	13,127	26	504.88	330.43	376.79
Sept. 27							2,551	11	231.91	10,944	26	420.92	326.42	324.21
Sept. 28	62	1	62.00				3,172	8	396.50	10,755	22	488.86	315.79	308.06
Sept. 29	490	2	245.00				1,147	9	127.44	947	2	473.50	281.98	235.42
Sept. 30	100	1	100.00							1,638	14	117.00	108.50	

BOATS OF GROUP II

[Catches delivered Point Ellis to Wilson Cove]

Day	1926 Barrels caught	1926 Deliveries	1926 Average delivery	1927 Barrels caught	1927 Deliveries	1927 Average delivery	1928 Barrels caught	1928 Deliveries	1928 Average delivery	1929 Barrels caught	1929 Deliveries	1929 Average delivery	Average delivery for four years unweighted	Average delivery for four years smoothed by threes
June 1				188	2	94.00	105	1	105.00	241	6	40.17	79.72	
June 2				1,154	7	164.86	205	5	41.00	117	1	117.00	107.62	102.36
June 3				686	4	171.50				68	1	68.00	119.75	95.44
June 4				1,002	13	77.08	15	1	15.00	763	9	84.78	58.95	99.65
June 5				154	2	77.00	938	9	104.22	1,975	11	179.55	120.26	99.07
June 6				220	1	200.00	287	5	57.40	1,159	12	96.58	117.99	119.09
June 7				242	2	121.00	1,182	11	107.45	900	7	128.57	119.01	125.34
June 8				1,603	15	106.87	2,618	16	163.63	1,292	9	143.56	138.02	123.32
June 9	43	1	43.00	1,824	9	202.67	1,292	19	68.00	138	1	138.00	112.92	136.02
June 10				1,257	8	157.13							157.13	205.24
June 11	671	1	671.00	1,506	15	100.40				1,859	7	265.57	345.66	214.60
June 12				264	5	52.80	1,778	9	197.56	1,381	8	172.63	141.00	290.46
June 13	632	1	632.00				3,443	11	313.00	1,255	6	209.17	384.72	249.77
June 14	813	2	406.50	155	2	77.50	1,447	7	206.71	2,037	10	203.70	223.60	271.88
June 15	651	2	325.50	756	9	84.00	4,533	14	323.79	1,439	15	95.93	207.31	231.36
June 16	460	1	460.00	371	3	123.67	2,676	13	205.85				263.17	228.56
June 17	662	3	220.67	883	5	176.60	354	1	354.00	219	2	109.50	215.19	239.66
June 18	210	1	210.00	2,192	17	128.94	305	1	305.00	4,459	14	318.50	240.61	213.78
June 19	252	2	126.00	78	1	78.00	3,660	13	281.54	2,823	11	256.64	185.55	218.86
June 20				160	2	80.00	2,931	11	266.45	6,551	19	344.79	230.41	214.90
June 21	472	2	236.00	1,087	5	217.40	1,894	13	145.69	4,738	15	315.87	228.74	213.25
June 22	187	1	187.00	2,194	12	182.83	924	5	184.80	3,920	18	217.78	180.60	195.63
June 23	64	1	64.00	3,198	12	266.50	3,639	18	202.17				177.56	204.20
June 24				3,210	15	214.00	308	1	308.00	4,344	18	241.33	254.44	201.87
June 25	361	2	180.50	3,794	17	223.18	548	2	274.00	2,367	12	197.25	173.61	196.57
June 26	40	1	40.00	43	2	21.50	3,755	9	417.22	2,518	15	167.87	161.65	181.95
June 27				313	3	104.33	4,243	14	303.07	2,468	11	224.36	210.59	193.08
June 28	338	2	169.00	2,065	9	229.44	4,680	16	292.50	1,645	12	137.08	207.01	230.86
June 29	482	2	241.00	1,559	7	222.71	4,410	13	339.23	5,345	18	296.94	274.97	215.25
June 30	278	2	139.00	765	7	109.29	3,889	16	243.06				163.78	222.75

July 1	230	1	230.00	4,301	14	307.21				454	3	151.33	229.51	228.83
July 2	372	1	372.00	7,456	22	338.91	557	2	278.50	1,284	7	183.43	293.21	238.53
July 3	456	3	152.00	281	1	281.00	1,425	6	237.50	404	4	101.00	192.88	199.94
July 4							1,982	13	152.46	375	5	75.00	113.73	200.90
July 5				6,674	17	392.59	3,002	11	272.91	1,114	5	222.80	296.10	204.91
July 6	401	2	200.50	5,626	19	296.11	1,314	8	164.25	2,222	14	158.71	204.89	227.84
July 7	255	1	255.00	1,439	7	205.57	1,393	16	87.06				182.54	168.09
July 8	457	3	152.33	170	3	56.67				566	4	141.50	116.83	158.40
July 9	614	2	307.00	336	7	48.00				2,070	12	172.50	175.83	133.81
July 10	277	2	138.50				1,030	9	114.44	954	13	73.38	108.77	148.29
July 11	594	2	297.00	218	2	109.00	1,143	9	127.00	865	8	108.13	160.28	133.44
July 12	353	2	176.50	140	3	46.67	769	5	153.80	1,185	8	148.13	131.28	130.90
July 13	30	1	30.00	1,193	9	132.56	358	4	89.50	1,830	12	152.50	101.14	108.66
July 14				862	9	95.78	1,187	13	91.31				93.55	126.67
July 15	597	2	298.50	649	9	72.11							185.31	181.68
July 16	218	1	218.00	522	9	58.00	1,306	6	217.67	571	1	571.00	266.17	215.37
July 17							2,382	12	198.50	1,717	9	190.78	194.64	216.77
July 18	357	1	357.00	462	3	154.00	2,580	12	215.00	32	1	32.00	189.50	188.37
July 19	491	2	245.50	1,352	8	169.00	1,493	12	124.42	1,295	7	185.00	180.98	186.89
July 20	758	3	252.67	659	5	131.80	900	5	180.00	1,767	9	196.33	190.20	207.13
July 21	161	1	161.00	1,591	9	176.78	1,164	12	97.00	566	1	566.00	250.20	204.39
July 22	700	2	350.00	1,209	9	134.33	34	1	34.00				172.78	226.69
July 23	570	2	285.00	2,251	17	132.41	1,569	8	196.13	2,904	7	414.86	257.10	225.21
July 24	744	2	372.00	297	2	148.50	2,385	12	198.75	3,165	12	263.75	245.75	222.13
July 25	596	3	198.67	783	5	156.60	1,586	10	158.60	561	4	140.25	163.53	190.33
July 26	428	2	214.00	1,513	7	216.14	459	6	76.50	981	7	140.14	161.70	151.82
July 27	792	5	158.40	2,947	14	210.50	354	4	88.50	508	8	63.50	130.23	181.85
July 28				1,654	8	206.75	1,276	14	91.14	463	1	463.00	253.63	193.92
July 29	332	1	332.00	658	6	109.67	152	1	152.00				197.89	190.55
July 30	284	2	142.00	1,592	15	106.13	24	1	24.00	1,250	6	208.33	120.12	180.40
July 31	320	1	320.00				2,852	14	203.71	1,021	7	145.86	223.19	183.42
Aug. 1	1,681	5	336.20				1,353	10	135.30	1,195	8	149.38	206.96	195.36
Aug. 2	1,685	7	240.71	1,090	8	136.25	1,856	13	142.77	104	1	104.00	155.93	139.14
Aug. 3	3,246	9	360.67	1,226	9	136.22	16	1	16.00	947	9	105.22	154.53	163.50
Aug. 4	1,865	6	310.83	2,068	11	188.00	578	14	41.29				180.04	204.84
Aug. 5	3,168	10	316.80	3,061	12	255.08				1,072	4	268.00	279.96	244.97
Aug. 6	4,757	14	339.79	4,092	17	240.71				2,931	12	244.25	274.92	240.89
Aug. 7	2,864	11	260.36				414	3	138.00	525	5	105.00	167.79	196.12
Aug. 8	2,116	11	192.36				655	7	93.57	1,208	8	151.00	145.64	164.26
Aug. 9	1,536	5	307.20	2,397	10	239.70	712	8	89.00	163	2	81.50	179.35	157.19
Aug. 10	2,996	11	272.36	1,103	9	122.56	112	1	112.00	874	11	79.45	146.59	184.38
Aug. 11	3,997	12	333.08	2,008	7	286.86	2,006	9	222.89	66	1	66.00	227.21	185.92
Aug. 12	1,898	6	316.33	1,886	9	209.56	26	1	26.00				183.96	221.43
Aug. 13	5,709	17	335.82	2,917	13	224.38	873	4	218.25	1,638	7	234.00	253.11	224.20
Aug. 14	3,612	9	401.33				1,803	6	300.50	2,643	11	240.27	235.53	250.75
Aug. 15	4,655	13	358.08				2,475	12	206.25	1,359	6	226.50	263.61	238.33
Aug. 16	4,908	13	377.54	370	2	185.00	2,287	11	207.91	279	3	93.00	215.86	212.29
Aug. 17	4,369	13	336.08	285	6	47.50	961	6	160.17	687	8	85.88	157.41	197.80
Aug. 18	6,409	16	400.56	527	7	75.29	2,952	16	184.50				220.12	182.42
Aug. 19	1,424	5	284.80	164	3	54.67							169.74	175.59
Aug. 20	1,344	6	224.00	299	6	49.83							136.92	131.32
Aug. 21	32	1	32.00				1,431	8	178.88	51	1	51.00	87.29	332.58
Aug. 22	411	3	133.33				1,031	11	93.73				113.53	134.08
Aug. 23	1,339	7	191.29	1,720	8	215.00	792	4	198.00				201.43	135.47
Aug. 24	1,102	7	157.43	172	3	57.33	168	2	84.00	67	1	67.00	91.44	140.35
Aug. 25	316	2	158.00	731	7	104.43	1,587	13	122.08				128.17	118.87
Aug. 26	176	1	176.00							98	1	98.00	137.00	126.61
Aug. 27	96	1	96.00	227	3	75.67				517	3	172.33	114.67	176.36
Aug. 28							2,180	11	198.18	3,923	11	356.64	277.41	237.20
Aug. 29							1,145	7	163.57	4,279	9	475.44	319.51	260.93
Aug. 30	50	2	25.00	225	2	112.50	921	6	153.50	4,460	12	371.67	185.87	241.32
Aug. 31				281	2	140.50	487	6	81.17	5,209	12	434.08	218.58	190.31
Sept. 1				219	1	219.00	1,823	16	113.94				166.47	180.02
Sept. 2				155	1	155.00							155.00	140.90
Sept. 3				144	1	144.00	26	1	26.00	802	6	133.67	101.22	136.59

TABLE 13.—*Daily catches of herring from 1926 to 1929, inclusive, by boats of Group I and Group II*—Continued

BOATS OF GROUP II—Continued

Day	1926			1927			1928			1929			Average delivery for four years unweighted	Average delivery for four years smoothed by threes
	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery	Barrels caught	Deliveries	Average delivery		
	Number	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Number*	*Number*	*Barrels*	*Barrels*	*Barrels*
Sept. 4							1,258	9	139.78	502	3	167.33	153.56	142.54
Sept. 5							548	7	78.29	2,941	11	267.36	172.83	197.47
Sept. 6				1,067	3	355.67	1,107	8	138.38	2,432	8	304.00	266.02	239.22
Sept. 7							549	5	109.80	4,926	11	447.82	278.81	284.23
Sept. 8				486	1	486.00	1,946	15	129.73				307.87	270.14
Sept. 9				26	1	26.00				843	2	421.50	223.75	252.07
Sept. 10				11	1	11.00				4,382	10	438.20	224.60	237.61
Sept. 11							1,258	11	114.36	2,073	5	414.60	264.48	237.57
Sept. 12							269	4	67.25	3,040	8	380.00	223.63	173.62
Sept. 13				16	1	16.00	99	2	49.50				32.75	193.54
Sept. 14				715	2	357.50				582	2	291.00	324.25	159.00
Sept. 15							960	8	120.00				120.00	268.75
Sept. 16				362	1	362.00							362.00	298.72
Sept. 17				331	1	331.00				4,476	9	497.33	414.17	308.86
Sept. 18				54	1	54.00	251	1	251.00	585	4	146.25	150.42	234.61
Sept. 19							320	4	80.00	794	4	198.50	139.25	186.64
Sept. 20				794	2	397.00				574	4	143.50	270.25	252.56
Sept. 21				506	1	506.00	875	2	437.50	303	3	101.00	348.17	323.27
Sept. 22							2,811	8	351.38				351.38	337.02
Sept. 23				623	2	311.50							311.50	345.71
Sept. 24				143	2	71.50	468	1	468.00	2,333	4	583.25	374.25	365.32
Sept. 25							2,988	9	332.00	2,442	5	488.40	410.20	394.08
Sept. 26							1,964	6	327.33	1,873	4	468.25	397.79	383.33
Sept. 27							527	2	263.50	1,682	4	420.50	342.00	391.35
Sept. 28							2,273	7	324.71	2,719	5	543.80	434.26	273.75
Sept. 29							135	3	45.00				45.00	200.84
Sept. 30							60	1	60.00	373	2	186.50	123.25	

Table 14.—*Daily catches of herring from 1926 to 1928, inclusive, by boats of Group III*

[Catches delivered north of Wilson Cove]

Day	1926			1927			1928			Average delivery for three years unweighted	Average delivery for three years smoothed by threes
	Number of barrels caught	Number of deliveries	Average delivery	Number of barrels caught	Number of deliveries	Average delivery	Number of barrels caught	Number of deliveries	Average delivery		
June 1											
June 2				800	2	400.00	98	1	98.00	249.00	
June 3											
June 4				417	3	139.00				139.00	
June 5				462	2	231.00	105	1	105.00	168.00	143.50
June 6	151	1	151.00				192	2	96.00	123.50	124.39
June 7	51	1	51.00				337	3	112.33	81.67	151.14
June 8	343	2	171.50	1,300	4	325.00				248.25	175.20
June 9	185	1	185.00	506	2	253.00	596	4	149.00	195.67	221.96
June 10											234.23
June 11	332	2	166.00	1,317	3	439.00	640	3	213.33	272.78	153.14
June 12				67	2	33.50				33.50	172.01
June 13	597	2	298.50				242	2	121.00	209.75	170.51
June 14	975	2	487.50	180	1	180.00	412	3	137.33	268.28	224.12
June 15	921	3	307.00	200	1	200.00	76	1	76.00	194.33	216.95
June 16				276	1	276.00	603	6	100.50	188.25	238.03
June 17	663	2	331.50							331.50	261.54
June 18	640	2	320.00	839	4	209.75				264.88	318.03
June 19	421	1	421.00				1,472	5	294.40	357.70	304.53
June 20	370	2	185.00				397	1	397.00	291.00	342.30
June 21	363	1	363.00	397	1	397.00	1,873	5	374.60	378.20	332.33
June 22	420	1	420.00	672	3	224.00	1,018	3	339.33	327.78	302.10
June 23	360	2	180.00	234	1	234.00	374	2	187.00	200.33	252.44
June 24	619	3	206.33	787	3	262.33	438	2	219.00	229.22	259.84
June 25	530	2	265.00	970	3	323.33	923	2	461.50	349.98	300.62
June 26				198	1	198.00	1,342	3	447.33	322.67	304.22
June 27	110	1	110.00				1,110	3	370.00	240.00	277.67
June 28	307	2	153.50				1,936	5	387.20	270.35	322.12
June 29							456	1	456.00	456.00	323.59
June 30	150	1	150.00	1,238	5	247.60	2,014	6	335.67	244.42	321.31
July 1	527	2	263.50							263.50	221.31
July 2				468	3	156.00				156.00	216.44
July 3	130	2	65.00	286	1	286.00	2,369	7	338.43	229.81	192.91
July 4											232.66
July 5	45	1	45.00	852	2	426.00				235.50	267.74
July 6	97	2	48.50	483	1	483.00	1,842	5	368.40	299.97	278.19
July 7	970	3	323.33	588	2	294.00	840	3	280.00	299.11	225.69
July 8	34	1	34.00	122	1	122.00				78.00	157.45
July 9	60	1	60.00	261	2	130.50				95.25	86.63
July 10											171.50
July 11	880	2	440.00				111	2	55.50	247.75	298.04
July 12	510	2	255.00	534	3	178.00	612	1	612.00	348.33	308.19
July 13	870	2	435.00				666	3	222.00	328.50	276.28
July 14	374	2	187.00				234	2	117.00	152.00	241.72
July 15	678	2	339.00	342	2	171.00	224	1	224.00	244.67	180.78
July 16	98	1	98.00	176	4	44.00	295	1	295.00	145.67	207.45
July 17	320	2	160.00				608	2	304.00	232.00	223.39
July 18	420	1	420.00				330	2	165.00	292.50	211.28
July 19	69	1	69.00	74	2	37.00	222	1	222.00	109.33	237.00
July 20	667	2	333.50	636	2	318.00	276	1	276.00	309.17	184.83
July 21	312	1	312.00	80	1	80.00	32	2	16.00	136.00	207.72
July 22	300	1	300.00	56	1	56.00				178.00	173.83
July 23	638	2	319.00	480	5	96.00				207.50	176.00
July 24	241	1	241.00				44	1	44.00	142.50	164.78
July 25	486	2	243.00				137	3	45.67	144.34	143.42
July 26											184.40
July 27	1,112	4	278.00	419	3	139.67	767	3	255.67	224.45	181.67
July 28	1,082	3	360.67	42	1	42.00	14	1	14.00	138.89	185.73
July 29	370	2	185.00	608	3	202.67				193.84	165.60
July 30	742	3	247.33	404	5	80.80				164.07	238.89
July 31	1,435	4	358.75							358.75	284.61
Aug. 1	662	2	331.00							331.00	286.36
Aug. 2	883	3	294.33				133	3	44.33	169.33	262.74
Aug. 3	1,822	4	455.50	481	4	120.25				287.88	227.46
Aug. 4	1,805	5	361.00	329	2	164.50	450	3	150.00	225.17	263.77
Aug. 5	757	2	378.50	178	1	178.00				278.25	242.60
Aug. 6	1,267	4	316.75	528	4	132.00				224.38	241.79
Aug. 7	743	2	371.50				74	1	74.00	222.75	245.46
Aug. 8	790	4	197.50				762	2	381.00	289.25	338.50
Aug. 9	1,007	2	503.50							503.50	360.69
Aug. 10	850	2	425.00	771	3	257.00	372	2	186.00	289.33	334.20
Aug. 11	1,937	5	387.40	254	3	84.67	629	4	157.25	209.77	241.28
Aug. 12	795	2	397.50	52	1	52.00				224.75	199.34
Aug. 13	1,736	4	434.00	87	2	43.50	13	1	13.00	163.50	225.31
Aug. 14	863	3	287.67							287.67	189.98
Aug. 15	790	3	263.33	16	1	16.00	154	2	77.00	118.78	197.32
Aug. 16	1,652	4	413.00	44	1	44.00	199	2	99.50	185.50	151.93
Aug. 17	303	2	151.50							151.50	170.13
Aug. 18	1,941	5	388.20	58	1	58.00	222	3	74.00	173.40	207.63
Aug. 19	475	1	475.00	242	2	121.00				298.00	219.23
Aug. 20	1,558	5	311.60	183	3	61.00				186.30	242.15
Aug. 21											184.40

TABLE 14.—*Daily catches of herring from 1926 to 1928, inclusive, by boats of Group III*—Continued

Day	1926			1927			1928			Average delivery for three years unweighted	Average delivery for three years smoothed by threes
	Number of barrels caught	Number of deliveries	Average delivery	Number of barrels caught	Number of deliveries	Average delivery	Number of barrels caught	Number of deliveries	Average delivery		
Aug. 22	365	2	182.50							182.50	145.07
Aug. 23	901	4	225.25	122	2	61.00	110	3	36.67	107.64	166.71
Aug. 24							210	1	210.00	210.00	149.49
Aug. 25	283	2	141.50	266	2	133.00	354	3	118.00	130.83	134.61
Aug. 26				126	2	63.00				63.00	86.94
Aug. 27				134	2	67.00				67.00	113.33
Aug. 28	210	1	210.00							210.00	228.50
Aug. 29	300	1	300.00				217	2	108.50	408.50	309.25
Aug. 30											251.75
Aug. 31	95	1	95.00							95.00	104.63
Sept. 1	107	2	53.50				525	3	175.00	114.25	104.50
Sept. 2											149.63
Sept. 3							185	1	185.00	185.00	182.13
Sept. 4	160	1	160.00				397	2	198.50	179.25	171.42
Sept. 5	150	1	150.00							150.00	118.08
Sept. 6							25	1	25.00	25.00	85.33
Sept. 7	20	1	20.00				61	1	61.00	81.00	90.67
Sept. 8							332	2	166.00	166.00	

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FACTORS INFLUENCING THE SPAWNING AND SETTING OF OYSTERS IN GALVESTON BAY, TEX.[1]

By A. E. HOPKINS, Ph. D., *Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

The problems of oyster culture in the waters of the South Atlantic and Gulf coasts are decidedly different from those in the waters of the North Atlantic coast although the oysters are of the same species (*Ostrea virginica*). On the Gulf coast the bays and estuaries are very shallow, and so the waters are readily affected by heavy rains and freshets as well as by differences in air temperature. The natural oyster beds, or reefs, are generally confined to a relatively narrow place between high and low tide levels and slightly deeper, and seldom occur more than 2 or 3 feet below low-water level. In more northern waters natural oyster grounds may be under 30 or more feet of water.

Few actual oyster-cultural operations are carried on in Texas waters and the industry is limited chiefly to the removal and marketing of oysters from the public reefs. In the past this method has sufficed to supply the demand to a large extent, and the necessity for intensive oyster culture on private grounds has not been pressing. In recent years, however, the oyster production of Texas, like that of many other States, has diminished, and increasing thought has been given to the possibilities of oyster culture by private individuals or companies. The Texas Game, Fish, and Oyster Commission is strongly in favor of production of oysters by private interests and has been attempting to pass legislation to permit the leasing of portions of productive public reefs as a stimulus to private enterprise. (Burr, 1928.)

It was the purpose of this investigation to learn some of the more important facts concerning the reproduction of the oyster in Texas waters and on the basis of this information to make suggestions as to how best to develop ground for the production of oysters. Of greatest importance was the problem of finding means of obtaining seed oysters in abundance, and it was with this in view that these observations and experiments were made.

[1] Approved for publication Nov. 28, 1930.

It was not possible to make daily observations over the entire coast of Texas, and so the work was confined to certain portions of Galveston Bay, which is very similar to the other oyster-producing waters along the coast. The results are therefore considered to be typical and may apply to most of the bays along the Gulf coast.

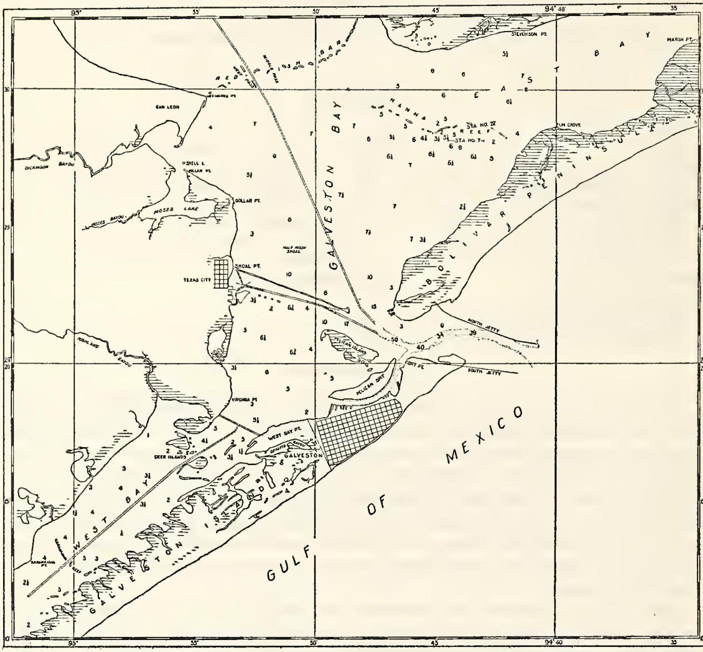

FIGURE 3.—Chart showing the major portion of Galveston Bay in which oysters are produced. Plankton collection station No. 7 and shell-planting station No. IV are indicated at Hanna Reef, in East Bay. See Figures 4 and 5 for West Bay and Offatts Bayou stations. (From U. S. Coast and Geodetic Survey Chart No. 1282)

A field laboratory [2] was built on the shore of Offatts Bayou (fig. 1), a portion of West Bay, and equipped with running sea water. This served as headquarters in which most of the observations were made.

METHODS

The most complete records were made in Offatts Bayou, for it is a small body of water and relatively calm even when the bay proper is rough. A pier extended out from the laboratory about 200 feet to the edge of the channel and on this the thermograph was placed. (Fig. 2.) The bulb was fixed slightly above bottom under about 2½ feet of water at low tide so as to give a fairly accurate record of water temperature without being exposed even at extreme low water. Continuous thermograph records

[2] The bureau is indebted to William J. Tucker, game, fish, and oyster commissioner of Texas, for furnishing the laboratory and equipment and a boat and boatman; also to W. A. Kelso for permitting the location of the laboratory on his property; and to Dolph Rogers for giving oysters as well as his time to assist in the investigation.

Figure 1.—Photograph of laboratory on the shore of Offatts Bayou near Galveston, showing a supply of shells in wire bags ready for planting

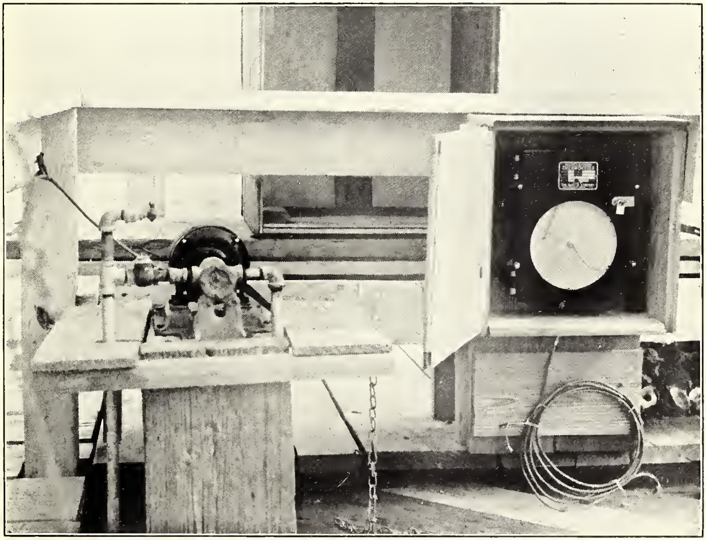

Figure 2.—Photograph of pump and thermograph on end of pier adjoining laboratory. The thermograph bulb was at the edge of the channel under 2½ feet of water at low tide

of water temperature were obtained over the period of six months from the end of February to the end of August, 1929.

Over the same period samples of water were taken at noon daily from the end of the pier and tested for salinity and hydrogen-ion concentration. Salinity was determined by means of specific gravity hydrometers, and hydrogen-ion concentration was tested colorimetrically by means of LaMotte comparators using phenol red, cresol red, and thymol blue as indicators. These results were not corrected for the small error due to salt variation.

Samples of plankton were taken as frequently as possible at 3 stations (fig. 5, stations 1, 2, and 3) in Offatts Bayou, 3 (fig. 4, stations 4, 5, and 6) in West Bay, and 1 (fig. 3, station 7) in East Bay. A plankton net of No. 20 bolting silk was towed at slow speed for five minutes at each station and the sample preserved in formalin for

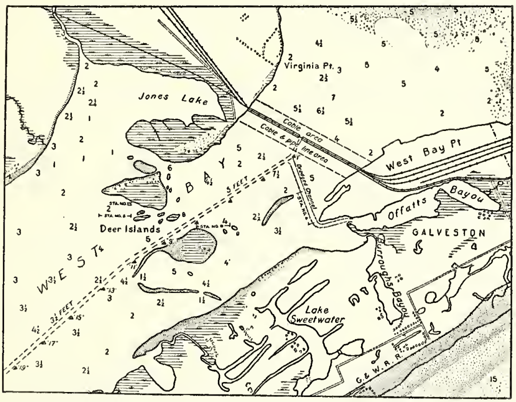

FIGURE 4.—Chart showing a portion of West Bay including plankton and shell-planting stations at the Deer Islands and near the mouth of Offatts Bayou. For stations in the bayou see Figure 5. (From U. S. Coast and Geodetic Survy Chart No. 1282)

analysis in order to establish the relative abundance of oyster larvæ and of diatoms. Whenever possible water samples were brought from the vicinity of Deer Islands (station 5) and Hanna Reef (station 7) and tested for pH and salinity. In this manner records were obtained which showed the physical characteristics of the water as well as the abundance of oyster larvæ and diatoms throughout the major part of the spawning season.

As a means of determining when setting of oyster larvæ takes place, oyster shells were planted periodically on the reefs at stations 1 and 2 in the bayou, station 3 at the Deer Islands, and station 4 on Hanna Reef. The shells were placed in bags, which were made of ½-inch mesh poultry wire and held about a half bushel of shells each. (Fig.1.) Descriptions of such bags have been published by Prytherch (1930a). Shells from the Bolivar cannery were used because they were thoroughly clean. By planting these bags of shells periodically in favorable places it was possible to determine when setting occurred. There was no possibility of the shells becoming slimy, for they were frequently exchanged.

DESCRIPTION OF OFFATTS BAYOU

Since many of the observations reported in the following pages were made in the bayou some description of this small body of water is essential. (Fig. 5.) It is about 2 miles long and varies from less than a quarter mile to about a half mile in width, and extends from West Bay into Galveston Island toward the Gulf. It is said that it is what remains of an old inlet connecting the bay and the Gulf. Though formerly shallow like most other such bayous along this coast, a few years ago extensive dredging was done for the purpose of filling in low land on the island. An irregular channel (fig. 5) now extends throughout most of the length of the bayou and is 30 feet or more deep. Portions of the bayou, however, still remain shallow and on these are excellent private oyster grounds which produce well-shaped, fat oysters. The deep channel insures a fairly rapid exchange of water with West Bay and would not be expected to suffer great changes in salinity due to local rainfall. Three regular

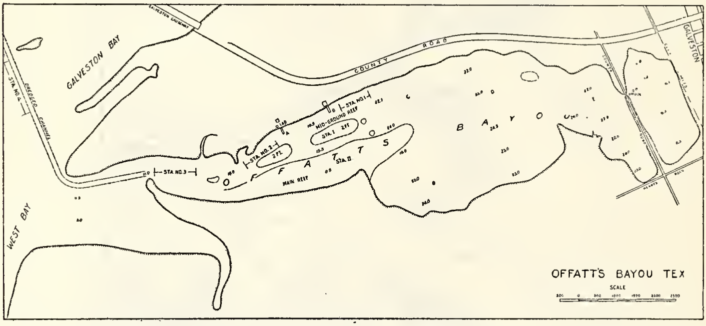

FIGURE 5.—Chart of Offatts Bayou showing oyster reefs, channels, and stations where shells were planted and plankton samples collected. See description in text. The laboratory was on the bank opposite the point marked A. Chart is based on preliminary survey by United States Engineers. Locations of oyster reefs indicated by Dolph Rogers, Galveston

stations for plankton collections and two for the planting of bags of shells are indicated on the chart.

THE SPAWNING SEASON

It has long been known that the spawning season of oysters in southern waters is very long, as compared to the short season in Long Island Sound, for example. (Prytherch, 1929.) Moore (1907) concluded from a study of Matagorda Bay that the major spawning in Texas waters takes place between May and early August. Later Moore and Danglade (1915) said that most of the spawning season was limited between May 1 and October 1. These conclusions were drawn largely from observations on the setting season, which, as will be shown, need not be closely similar to the spawning period.

It has been established that oysters do not spawn until after the water temperature reaches 20° C. (Churchill, 1920; Nelson, 1928; Prytherch, 1929; Galtsoff, 1930), and that the length of the spawning season is limited, therefore, by temperature. Oysters from Galveston Bay were examined frequently during February and March (1929) in an attempt to locate as nearly as possible the exact time of appearance of well-formed eggs and active sperms in the gonads.

The first oysters which were found to be somewhat "milky" were taken on March 18 in the bayou. Only an occasional specimen, however, contained either well-formed eggs or active sperms. On March 23 a similar condition was found in

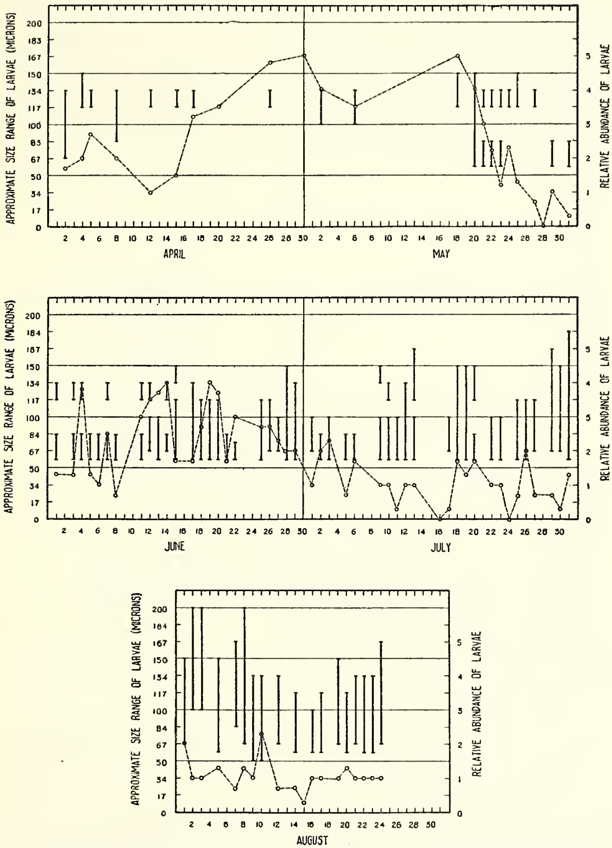

FIGURE 6.—Showing approximate size and relative abundance of oyster larvæ in plankton samples taken in Offatts Bayou, April to August, 1929. Size range of larvæ in microns of shell length is shown as vertical lines corresponding to values of ordinates shown on left of graphs. Relative abundance of larvæ was estimated as follows: 0, none; 1, very few; 2, few; 3, fair number; 4, many; 5, very many. Larvæ 150 microns or more in length are in umbo stage and closely approaching maturity

oysters taken from both East and West Bays. On the 29th all specimens from the bayou which were examined contained mature eggs or sperms, and some appeared to have spawned partially. On April 5 specimens from East and West Bays also appeared to have started spawning.

Oyster larvæ were taken for the first time in plankton collections on March 28 in the bayou. These were not numerous and were of the late straight-hinge stage, or presumably 2 to 3 days old. This is in substantial agreement with the observations on the gonads of the oyster and establishes the initiation of spawning on about March 25.

A quantitative method of measuring the abundance of oyster larvæ in plankton collections was not employed, for while such a measure might be feasible during a few weeks it would be too time consuming over a period of several months. A crude method of approximation of abundance was devised which gave values of relative significance. After immediate examination to determine if larvæ were present the

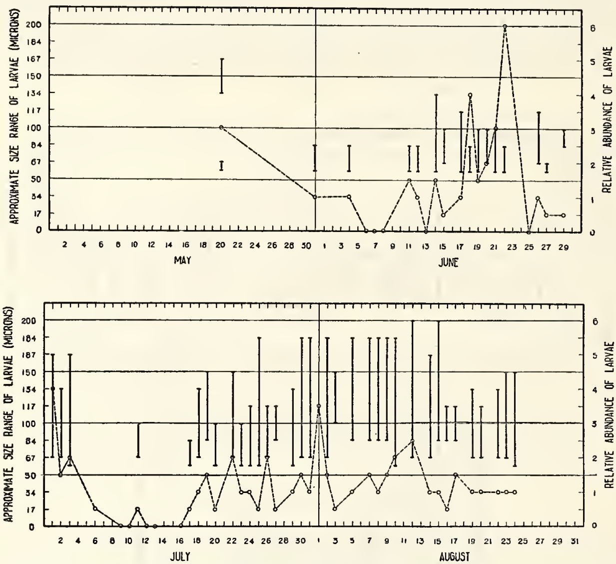

FIGURE 7.—Charts showing the relative abundance (circles) and approximate size (vertical lines) of oyster larvæ taken in plankton collections at Deer Islands from May to August, 1929. Size refers to length of larval shell in microns. Relative abundance was estimated as follows: 0, none; 1, very few; 2, few; 3, fair number; 4, many; 5, very many; 6, extremely abundant

samples of plankton were preserved and kept until the end of the summer. Then, over a relatively short period, to insure accuracy, the abundance of larvæ in each sample was estimated by an arbitrary standard. Numbers from 0 to 6 were employed to designate from none to extremely abundant and were defined as follows: 1, very few; 2, few; 3, fair number; 4, many; 5, very many; and 6, extremely abundant. All collections were made in the surface 12 to 15 inches of water and these figures refer only to the presence of larvæ at this level. However, since larvæ were taken in nearly every collection after the end of March it is probable that the collections represent a reasonable estimate of the abundance of larvæ in the water, or the intensity of spawning.

The general size range of the larvæ in each sample was determined by measuring the length of a number of specimens with a micrometer scale. The purpose was primarily to obtain an idea of the age, or growth stage, of the larvæ. In Figure 6 graphs are presented to show both the relative abundance and the size range of larvæ taken in plankton collections in Offatts Bayou from April 1 until the end of August. Collections during the latter part of April and the beginning of May were infrequent, but the results of these samples are entirely consistent. It will be observed that during early April larvæ in the collections were not abundant, indicating that spawning had not reached its maximum. After the middle of April, however, the curve is very high showing the great abundance of oyster larvæ. This abundance of larvæ continued until the middle of June and from then until the end of August, when collections were discontinued, the number of larvæ taken became constantly less numerous.

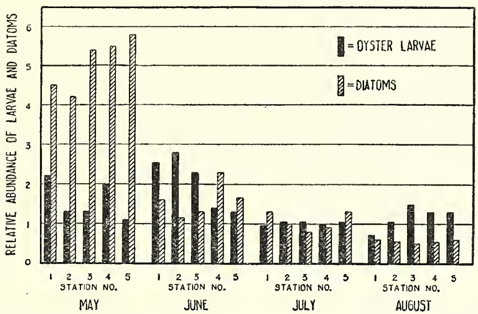

FIGURE 8.—Chart showing the relative abundance of oyster larvæ and diatoms, in plankton samples taken at stations 1 to 5 (figs. 4 and 5), as averages of all collections during each month from May to August. Relative abundance is designated by ordinates as in Figures 6 and 7. The rapid disappearance of diatoms is contrasted with the relatively slow reduction in number of larvæ taken

The period of greatest abundance of larvæ in the water appears to have been from the middle of April to the middle of June. Since these larvæ were predominantly in the straight-hinge stage, or within about 3 days old presumably, the records may be considered to indicate the period of most profuse spawning. However, in July and August spawning continued, as shown in Figure 6, at a diminished rate, and almost every collection contained larvæ. The collections made at the Deer Islands (fig. 7) were essentially similar to those made in the bayou, as described above, though few samples were taken before the end of May.

Figure 8 is presented to show the monthly average abundance of larvæ taken in collections at stations 1 to 6. The abundance of diatoms is also given in this figure. (See section on diatoms.) Stations 1, 2, and 3 were in the bayou; station 4 in West Bay outside the bayou inlet; and stations 5 and 6, which are averaged as of one station numbered 5, at the Deer Islands. (See charts, figs. 4 and 5.) The relative abundance of larvæ at each station was determined by averaging the figures designating the abundance of larvæ in all collections taken at each station during each month, from

May to August. April was not included in this because of the relative infrequency of the collections. The figure shows that the peak of spawning occurred in May and June, particularly the latter. The August collections at stations 4 and 5–6 in West Bay and station 3 in the bayou inlet contained somewhat more larvæ than in July, indicating a possible acceleration of spawning at this time.

Observations were brought to a close at the end of August, and it is not known how much longer spawning continued. From the records, however, it may be concluded that the spawning season was far from complete at this time. (See figs. 6, 7, and 8.) It may be assumed that the season continued for at least another month and possibly even longer. From the end of March until the end of August—a period of five months—spawning occurred apparently continuously, and it is reasonable to assume that the usual spawning period covers at least six months. During the time after spawning started only very occasional samples were taken which contained no larvæ, and these were taken in stormy weather when the silt in the water clogged the net and rendered the collections of little significance.

On the graphs showing daily abundance of larvæ in the bayou (fig. 6) and at Deer Islands (fig. 7) the size range of the larvæ taken is also indicated. Larvæ in the straight-hinge stage are less than about 150 microns in length, while those 150 microns or more long are in the umbo stage. At about 200 microns length the larvæ are close to the setting stage. Most larvæ taken throughout the season were in the straight-hinge stage, and only at certain periods did umbo larvæ appear. It would seem that the larvæ either did not develop rapidly or else died before becoming mature, for the presence of large larvæ in the water was closely associated with the appearance of spat. This is discussed more fully in the section on setting and need not be described further here.

SEX OF OYSTERS

While making examinations of oysters during the spring and summer, records were kept of the number of specimens of each sex. At irregular intervals small lots of unselected oysters were brought in from various reefs for the purpose of determining whether mature eggs were present in the gonads. The records showed, incidentally, a great predominance of females. Determinations made by Dr. Paul S. Galtsoff as well as those by the author are given in Table 1. In a few cases some specimens were either too completely spawned out or immature to permit ready determination of sex. In the table these are recorded as *doubtful.* Out of 252 oysters examined 178 were females, 51 were males, and 23 were of doubtful sex. More than three times as many females were taken as males, although the samples were taken in small lots at different times from different places. In each lot examined, males were outnumbered by females. Even if all of the specimens considered doubtful were males there would still be more than twice as many females.

It hardly seems possible that these results do not indicate the presence of more female than male oysters in this vicinity, although it has generally been found on the Atlantic coast that the two sexes are equally numerous.

TABLE 1.—*Sex of oysters in Galveston Bay*

Date	Place	Males	Females	Doubtful[1]
1929				
Apr. 15 [2]	Bayou, main reef	1	11	0
Apr. 16 [2]	do	3	21	0
Apr. 17 [2]	do	2	18	0
Apr. 29	do	6	12	2
	Bayou, middle ground	7	9	0
May 7	Bayou, main reef	2	12	6
	Bayou, middle ground	1	8	3
May 9	Bayou, main reef (top)	7	11	0
	Bayou, main reef (south side)	1	5	0
	Bayou, main reef (north side)	2	6	0
	Bayou, middle ground	2	12	0
June 12	do	5	12	5
June 13	Deer Island reef	2	10	1
June 14	Bayou, main reef	5	10	3
July 11	Deer Island reef	2	7	3
July 12	Bayou, main reef	3	14	0
Total		51	178	23
Percentages		20.24	70.63	9.13

[1] Specimens which were either spawned out or immature, the sex of which was not readily determined.
[2] Counts made by Dr. Paul S. Galtsoff.

WATER TEMPERATURE IN RELATION TO SPAWNING

The daily temperature of the water in Offatts Bayou is given in Figure 9 as the average of readings from the thermograph chart at each of the 24 hours daily. The bulb of the thermograph was under about 2½ feet of water at mean low tide.

At the end of February and the beginning of March (fig. 9) the temperature was between 14° and 15° C., from which it rose, by the middle of March, to 18° to 19° C. The major spring rise in water temperature, however, took place in the latter half of March. The temperature passed 20° C. on March 21, and six days later was over 25° C. The initiation of spawning as a response to rise in temperature is well illustrated here, for the first larvæ were found in the water on the 28th. However, instead of appearing immediately after the temperature reached 20° C., their appearance is more closely coordinated with the 25° C. level. This indicates that there is considerable lag between the time the water temperature reaches 20° C. and the time spawning begins. In fact it is very probable that the surface water, in which the oyster reefs are located, reached 20° C. well in advance of the time that the average temperature of the deeper water, as shown in the figure, attained this level.

The thermograph records show that even at a depth of 2½ feet the temperature was maintained for several hours at 20° C. as early as March 7. For 13 hours on March 9 it was between 20° and 22° C. On the 10th it was for 8 hours between 20° and 21° C. From the 10th until the 20th the maximum temperature shown on the charts was well over 19° C. Since the spring rise in temperature, beginning early in March, was due naturally to air temperature and sunshine it is probable that throughout the early part of the month the temperature of the water at the level of the oyster beds was 20° C. or above during most of the daylight hours, yet no larvæ were found in the water and the oysters appeared to be mostly unready to spawn.

On the basis of these observations, it would be impossible to state that 20° C. is the critical temperature for spawning of oysters on the Gulf coast. However, Galtsoff (1930) showed experimentally that spawning will not occur below 20° C. but at this or higher temperatures it will take place when the specimens are adequately stimulated. From field observations on the Atlantic coast it was concluded by Churchill (1920), Nelson (1928), and Prytherch (1929) that spawning begins shortly after the water

attains 20° C. While in Galveston Bay the temperature was sufficiently high during part of the time early in March, no spawning took place because the germ cells in the gonads had not reached maturity. No well-formed eggs or active sperms were found in the oysters before March 18. Because of the very rapid spring rise in water tem-

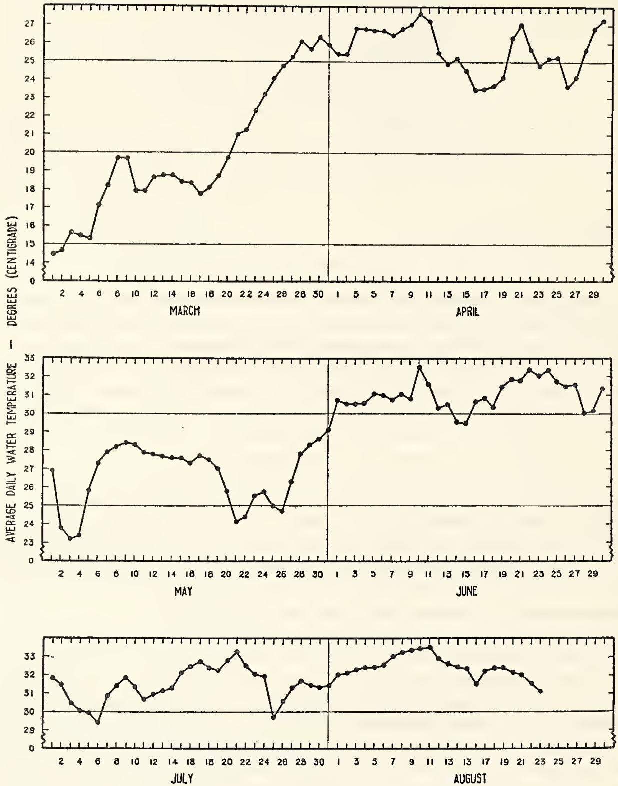

FIGURE 9.—Charts showing daily temperature of water in Offatts Bayou, Galveston, from March to August, 1929. Daily temperature was calculated as the average of the 24 hourly thermograph readings. The thermograph bulb was about 2½ feet below low tide level at the edge of a 30-foot channel

perature the critical temperature for spawning was reached in advance of maturation of the gonads.

The maximum of the spawning period occurred in May and June, during which time the water temperature was usually well above 25° C. and had been so since the end of March. This is strikingly in contrast to the observations of Prytherch

(1929) in Long Island Sound, where the entire season's spawning takes place within less than one month and can be predicted on the basis of water temperature. In that place the oysters spawn completely within a short time, while in the Gulf waters the spawn is ejected slowly over long periods of time. About a month and a half was required for spawning to reach its maximum, while in Long Island Sound and similar waters the maximum is reached within a few days after the water reaches 20° C.

TABLE 2.—*Temperature in °C. of surface water, Galveston Bay, in summer, 1929*

Date	West Bay near mouth of bayou	West Bay near Deer Island Reef	East Bay near Hanna Reef	Date	West Bay near mouth of bayou	West Bay near Deer Island Reef	East Bay near Hanna Reef	Date	West Bay near mouth of bayou	West Bay near Deer Island Reef	East Bay near Hanna Reef
June 19	27.9	27.8	30.3	July 15	----------	----------	28.9	Aug. 7	29.7	30.0	----------
20	28.7	28.5	28.9	16	29.7	30.4	----------	8	30.0	30.7	----------
21	28.9	29.4	----------	17	30.0	29.1	----------	9	29.4	30.5	----------
22	31.3	31.1	----------	18	29.3	29.4	----------	10	30.5	30.8	----------
25	28.9	29.4	----------	19	30.0	30.0	----------	12	30.3	30.3	----------
26	28.4	28.7	----------	20	30.5	30.3	----------	13	----------	----------	31.6
27	28.9	29.4	----------	22	29.4	30.5	----------	14	30.0	30.0	----------
28	28.1	28.5	----------	23	29.7	30.2	----------	15	30.0	30.3	----------
29	27.5	27.2	----------	24	28.9	29.3	----------	16	29.4	29.7	----------
July 1	29.2	29.3	----------	25	27.5	27.2	----------	17	30.0	29.4	----------
2	29.4	28.9	----------	26	27.2	27.2	----------	19	29.7	30.0	----------
3	28.1	28.1	----------	27	28.3	28.3	----------	20	29.4	29.4	----------
5	27.8	----------	----------	29	28.3	28.3	----------	21	29.4	29.4	----------
6	27.3	27.2	----------	30	28.5	28.9	----------	22	29.6	29.4	----------
9	28.9	29.2	----------	31	28.9	28.9	----------	23	28.3	28.3	----------
10	29.4	29.7	----------	Aug. 1	28.9	29.2	----------	24	27.2	27.2	----------
11	28.3	28.9	----------	2	29.4	29.4	----------	26	28.6	28.6	----------
12	28.5	28.3	----------	3	29.5	29.7	----------	27	----------	----------	28.3
13	29.8	27.9	----------	5	30.4	30.5	30.5	28	29.2	28.9	----------
14	----------	----------	29.4	6	----------	----------	28.3				

The water temperature in the bayou fluctuated around 25° C. during April and May, and during June, July, and August seldom dropped below 30°. Temperatures between 30° and 33° C. are extremely high, as compared with the North Atlantic waters, but probably are not much above average during the summer for the bays on the Gulf coast. The high temperature of the water throughout a large part of the year is probably responsible for the rapid growth of oysters, which attain marketable size in two years.

In the open bay the temperature did not rise quite as high as in the bayou. In Table 2 records of separate readings of the temperature of surface water in both East and West Bays are given. Because of the exposure of these waters to wind the temperature in general ranged slightly below 30° C. during the summer.

SALINITY AND HYDROGEN-ION CONCENTRATION

Galveston Bay is subject to changes in salinity due to discharge from the San Jacinto and Trinity Rivers and innumerable small bayous which drain the mainland as well as to the direction and strength of the wind. Being a shallow bay it would be expected to exhibit marked changes in salinity, particularly as a result of swollen rivers.

Samples of bayou water, from the surface 6 inches, were tested daily for salinity and pH. Frequent tests were also made with samples from the Deer Islands in West Bay and Hanna Reef in East Bay. A brief description of the changes taking place in the water during spring and summer is necessary to show what is perhaps a semitypical example of the variation in the bay waters of most of the Gulf coast.

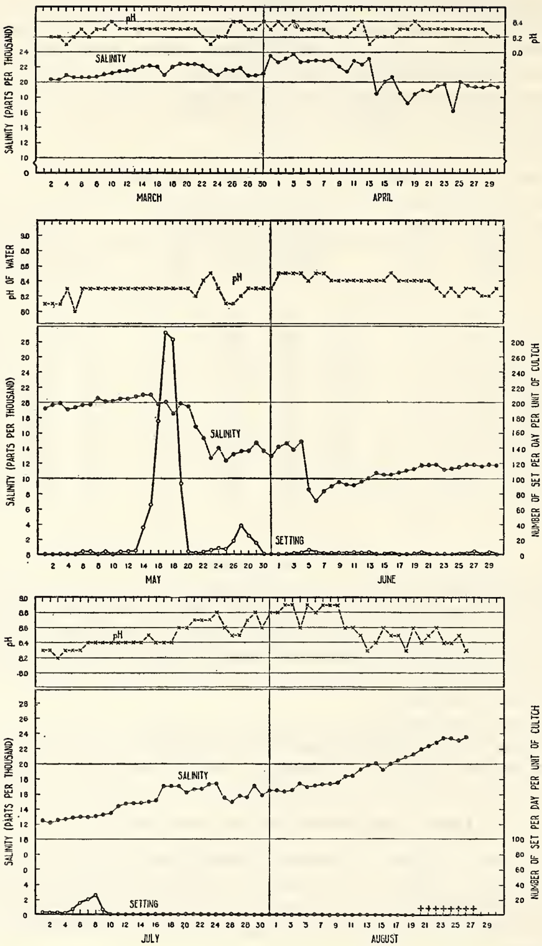

FIGURE 10.—Charts showing the daily salinity and pH of water (surface) in Offatts Bayou from March to August, inclusive, and the daily set from May to August in the same place. The period of heavy setting at the middle of May took place on both reefs, while the light setting at the end of May and early in July occurred on the middle ground reef only. Shells placed on reefs August 19 were examined on the 27th and found to have a fair set of small spat, though counts were not made (points marked +)

The records of Offatts Bayou water are shown in Figure 10, while those of the water at Deer Islands and East Bay are given in Figures 11 and 12. In the bayou during March and up until about the middle of April the salinity was 21 to 22 parts per thousand. It then fell slightly (fig. 10) to about 18 parts per thousand, slowly rising to 21 parts per thousand at the middle of May, before falling sharply to around 14 parts per thousand at the end of the month. Early in June it fell to 8 parts per thousand, and at the end of August it steadily rose to about 24 parts per thousand. Records for Deer Islands were not made until June (fig. 11) but after this time the

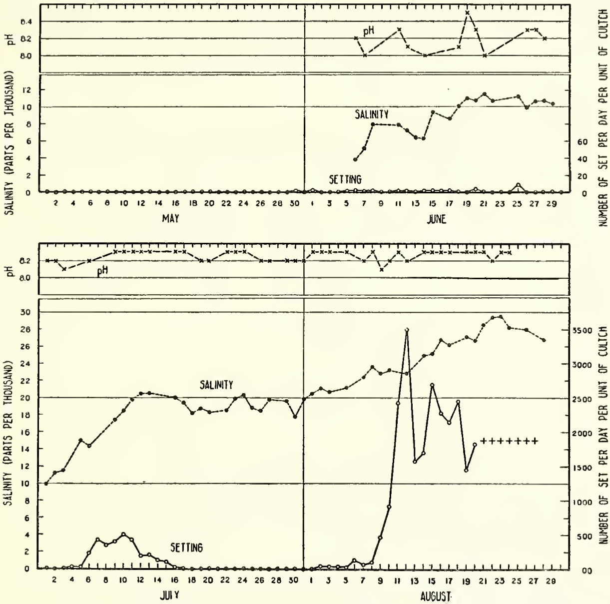

FIGURE 11.—Showing records of salinity and pH of surface water and intensity of oyster larvæ at Deer Islands from May to August, inclusive. After August 20 setting was occurring but counts were not made

salinity variations were essentially similar to those in the bayou save that, due to the larger size of West Bay and the free sweep of winds and tides, there is greater fluctuation. Early in June the salinity was below 4 parts per thousand and the water was almost fresh. In East Bay few tests were made, and these were as low as 2 parts per thousand in June. (Fig. 12.)

A more detailed description of the salinity variations is made in the section on setting.

The pH of the water, both in the bayou and in West Bay, appears to be characteristically between 8.1 and 8.4. Readings were found to agree closely when different indicators were employed. During the time that tests were made the

pH was seldom below 8, but in the bayou in August it rose to nearly 9, due probably to algal growth. The pH of the water was not observed to have any particular significance with regard to the spawning and setting of oysters.

OBSERVATIONS ON SETTING

It has been established by Prytherch (1929) that the usual period of larval development, from the time of spawning until the larvæ set, is about 15 days. By means of this knowledge he was able to predict in Long Island Sound the beginning of setting by determining the time when spawning started. Where conditions remain constantly favorable, such a method of obtaining set economically may be employed, but in Galveston Bay no such relationship between the times of spawning and setting

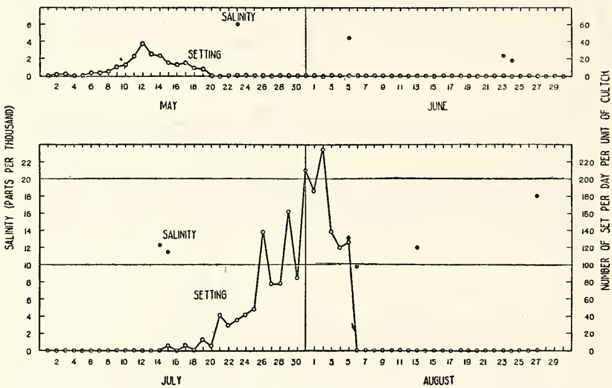

FIGURE 12.—Chart showing intensity of setting of oyster larvæ and a few salinity determinations at Hanna Reef, East Bay, from May to August, inclusive

was found to obtain. The oysters started spawning at the end of March, but no appreciable set was obtained at any place until the middle of May, after nearly two months had elapsed.

The problem of obtaining adequate set is the most important one in the industry, and an attempt was made to determine when periods of setting might be expected in order that they be taken advantage of to procure seed oysters. Obviously the time of spawning had little bearing upon the setting time in Galveston Bay, for factors other than the normal length of the larval period appeared to influence the maturation of the larvæ.

In order to determine as closely as possible the time when setting takes place, wire bags of shells were placed in favorable positions in the bayou (fig. 5, Stations I and II), in West Bay (fig. 4, Station III), and in East Bay (fig. 3, Station IV). At each station bags were placed both on top of the natural reef at approximately low-tide level or a few inches above and at the edge of the reef in 2–4 feet of water at low tide. Each bag of shells was numbered and the time and position of planting recorded. At intervals of one to three weeks new bags were planted in each place and representative ones of those that had been exposed in the water were brought to the

laboratory and examined carefully for spat. By constantly placing fresh, clean bags of shells on the beds adequate cultch was always available for larvæ of the setting stage. In this manner the possibility of the shells becoming too slimy to act as suitable setting places was eliminated. As a further control the oysters and shells of the natural reefs were examined from time to time in order to be sure setting was not taking place on those instead of on the planted shells. Bags of shells were periodically planted from early in March until late in August and examined for spat.

When it was found that the bags of shells bore spat, several such bags from the same place were examined to see roughly if the spat were of the same approximate size and abundance. Then all of the shells in one bag, or in two from the same place, were carefully examined and counts made of the total number of spat on the inside surfaces of the shells. Since this method requires the counting of young and minute spat it was not possible to make counts for more than a half bushel of shells in each case. Only those on the inside surfaces of the shells were counted because the outside surfaces of the shells were too rough to permit accuracy. The counts made are comparable, however, and refer to the number of spat on the inside surfaces of a half bushel of shells. The counts were more accurate for spat several days old than for those only one or two days after setting, because the latter were readily sloughed off in handling, especially after the shells had become dry.

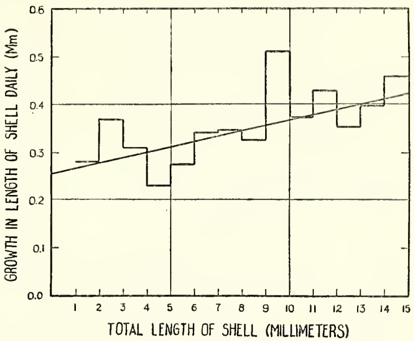

FIGURE 13.—Showing average daily growth in length of shell of oyster spat in relation to total length. The growth rate increases slightly with size. An ideal line is drawn to serve as a basis for calculations

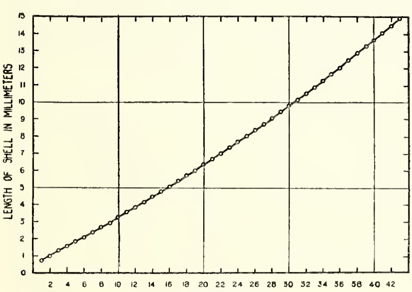

FIGURE 14.—Showing length of shell of oyster spat in relation to age, calculated from values on the ideal line in Figure 13. The curve, for growth of spat of the ages shown departs only slightly from a straight line

GROWTH OF SPAT

In the counts above described it would occur that the spat might range from less than 1 millimeter to 6 or 8 millimeters in length, the shells having been in the water for two or three weeks. It was considered desirable to attempt to define the intensity of setting more closely than over two or three week intervals. A roughly serviceable method was devised to give the number of larvæ setting daily at each

station. While not accurate to the day these results may be considered significant within plus or minus two or three days. In order to obtain figures of the rate of growth of the shells of spat, measurements of the length of 128 living spat were made, and the shells to which they were fixed placed back in the water in wire bags. These spat were of diverse sizes at the start. After four to six days they were taken up and measured again, and the amount of growth divided by the number of days was taken as the growth per day. Since the original spat ranged from 1 to 15 millimeters in length, the method suffices to show the relative amount of shell growth per day with regard to the total size of the shell. The results are presented in Figure 13. The abscissæ represent the length of the shells of the spat at the beginning in groups of 1 millimeter range, while the ordinates show the average growth in length. The amount of growth daily increases with size of the spat. Because of the individual variation the graph is not perfect, so a theoretical line was drawn to represent the increment in length per day. While not intended to be mathematically accurate this is of use in making it possible to gain an idea of the day on which the spat actually set. Calculating from this theoretical line the length of spat at different ages, a curve (fig. 14) is obtained, which for the spat up to about 40 days old is to all practical purposes a straight line. Certainly in proportion to the entire growth period of the oyster this would not be the case, but we are concerned here chiefly with spat of 20 days old or less. For this purpose it is considered that the growth or daily increase in size is constant.

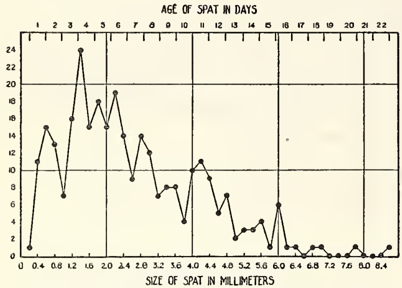

FIGURE 15.—Size distribution of 300 oyster spat on shells which were in water 22 days. At top of figure, divisions show age of spat with reference to size groups shown on lower axis

DETERMINING DATES OF SETTING

If a bag of shells bore a very heavy set, the spat were counted and then 300 of them were measured. To do this the shells were not selected and all spat on each shell used were measured. An adequate distribution was obtained therefore. One example is presented in detail below.

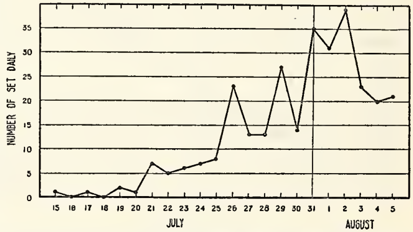

FIGURE 16.—Graph showing the data given in Figure 15, recalculated to indicate the date of setting of the 300 spat. Setting was rare in the middle of July but became more abundant up until the 1st of August

There were 1,800 spat on the half bushel of shells, and 300 of these were measured and their size distribution plotted. (Fig. 15.) The figure shows the predominance of the younger spat. The bag of shells had been in the water for 22 days, and the largest spat, therefore, could not be more than 22 days old. Some of the largest spat, according to the age curve (fig. 14) would appear to be older than this; but these

are rare and grew faster than average, for the individual variation is large. Apparently the oldest spat set soon after the shells were placed in the water. Then, since the growth rate may be considered constant, the abscissal axis representing size was divided up into 22 equal parts, as shown in the figure, each representing a day.

On the basis of these divisions the size range of the spat for each day was recorded and the measurements regrouped according to the day of setting. These data were then plotted as in Figure 16, which shows the relative number of larvæ which set each day. This is the approximate distribution of the 300 which were measured. Since there were 1,800 spat altogether, by multiplying each value by 6 the total number of larvæ setting daily per half bushel of shells was obtained.

It would be simple if it were possible to establish the age readily simply by referring to the age and size curve (fig. 14); but this would be less accurate because the spat grow more rapidly at some times and at some places than at others, due to depth of water and consequent temperature, etc. The method above described appears to be much more serviceable in indicating the approximate times of most profuse setting.

Similar counts and calculations were made throughout the summer with samples of shells which received a set. These results are grouped in three series according to location of the reefs on which the shells were planted and are presented graphically on the charts (figs. 10, 11, and 12) which show also salinity and pH of the water.

SETTING PERIODS DURING SEASON

Shells in wire bags were planted at two stations in the bayou. (Fig. 5, Stations I and II.) The main reef, on which Station II was located, is on one side of the channel and is relatively free from the tidal currents which flow back and forth. The "middle ground," however, (Station I), is an isolated shallow plot directly in the path of the currents and might be expected to be subject to relatively rapid changes in the water which flows in from West Bay during flood tide and out from the upper end of the bayou during ebb tide. This difference between the locations of the two bayou stations is important, for, in some cases, shells at one of the places received set while those at the other did not.

It has been pointed out that spawning was taking place at the end of March. From the observations of Prytherch (1929) that the larval period is about 15 days, it was expected that small spat would be found by the middle of April. However, no set was obtained on any reef during the entire month of April. During about six days at the middle of May (fig. 10) a period of setting took place at both stations in the bayou, but not in West Bay (fig. 11). At about the same period, or a few days earlier, a light set occurred in East Bay on Hanna Reef. At the end of June a few days of light setting occurred in the bayou, on the middle ground reef, but not on the main reef. Neither in West Bay nor in East Bay did any setting take place at this time.

Early in July a short period of relatively heavy setting occurred in West Bay. (Fig. 11.) The scale of ordinates on this figure is different from the others, and each unit is 12.5 times as great, in order to show the heavy setting which took place later. At the same time young spat were not found on shells in East Bay. However, there was a light set on the middle ground reef in the bayou but not on the main reef. At the end of July and beginning of August a 2-week period of setting occurred in East Bay, followed after a few days by continuous heavy setting in West Bay, but

not in the bayou. Observations were discontinued about August 20 and further counts were not made. However, shells put in the water on August 20 in both West Bay and the bayou collected spat, showing that setting had started again in the bayou and was continuing in West Bay. Up until the 27th there was no further set in East Bay.

These records, as shown in Figures 10, 11, and 12, indicate that whatever factors may have influenced the setting of the larvæ they were not equally effective in the three locations. Such natural variations as sunshine, temperature, and local precipitation would be virtually the same in all three places, and it is necessary to look further in order to obtain a suggestion of the factors controlling setting.

Table 3 gives a summary of the results of all counts of spat which were made. Except near the end of the season, in the case of the Deer Islands samples, setting was never extremely heavy. It was not a continuous process, as appears to have been true of spawning, but took place in isolated periods. It looks as if the time of major setting, during the season of 1929, was early fall, for at the end of August profuse setting was taking place both in West Bay and in Offatts Bayou, and in both places larvæ in the umbo stage were constantly found in the plankton collections. (Figs. 6 and 7.) According to local oystermen most of the set is often obtained early in the fall.

APPARENT INFLUENCE OF SALINITY ON SETTING

A comparison of the records of salinity with those of setting (figs. 10, 11, and 12) suggests the possibility that there may have been some connection between salinity of the water and maturation of the oyster larvæ. It has been pointed out that in Offatts Bayou the two reefs where bags of shells were planted were close together but that at times set was obtained on only one of them. This would indicate a difference in some respect between the water at the two places.

During March and up until April 13, the salinity of the water in the bayou was around 22 parts per thousand. However, on the morning of April 13 a heavy rain fell, and the next day the salinity was down to below 19 parts per thousand. This occurred at the time when the beginning of setting was expected. During the following four weeks the salinity rose very slowly and was about 21 parts per thousand at the middle of May for a few days. At this time and for a few days thereafter a fairly heavy set took place, amounting to about 1,000 spat per bag of shells. Spat were found on both reefs in the bayou, but not at the Deer Islands in the adjoining West Bay. The salinity then fell abruptly and setting ceased on the main reef.

A few days later, however, a light set occurred on the middle ground reef only. Since setting was not going on in West Bay this could not have been due to mature larvæ brought in from that place. Further, the marked lowering in the salinity of bayou water was due to the inflow of West Bay water, for the bayou is subject to almost no dilution by direct land drainage. It was observed consistently that changes in the salinity of West Bay water were only slowly transmitted to the water up in the bayou, so it would be expected that, following such a change, a salinity gradient would exist from end to end of the bayou. On June 6 a series of samples was taken from six places and tested for salinity. The first was at the Deer Islands, in West Bay, with a salinity of 3.73 parts per thousand. The others were taken from positions in the bayou indicated on the chart (fig. 5) by the letters A to E, extending from the laboratory dock to the head of the bayou. The salinity values in parts per thousand were as follows: A, 6.75; B, 7.25; C, 7.30; D, 7.43; and E, 8.57.

Figure 17.—Photograph of a clump of shells bearing young spat within 19 days old, for the shells were in the water only 19 days. Actual length of the main shell was 4 inches

This gradient of salinity in the bayou shows that the water least subject to change, as a result of the inflow of West Bay water, is that at the head of the bayou. These tests were made more than a week after the brief setting period on the middle ground reef took place, but yet show the presence of water of higher salinity at the inner end of the bayou.

The significance of this salinity gradient with regard to the light setting period which occurred at the end of May on the middle-ground reef is possibly that water of high salinity left in the inner end of the bayou moved outward along the channel at ebb tide and furnished adequate setting conditions along the main channel, in which the middle ground is located. Such water would not be expected to touch the main reef to the side, where no set took place. Such a condition would be expected when the salinity in West Bay is falling, and the bayou water is of a higher salinity.

When the situation is reversed, however, and the salinity of West Bay water is rising while that of bayou water follows, the water flowing into the channel at flood would be of higher salinity than that at ebb tide. This would also give opportunity for setting to occur on the middle-ground reef. This condition obtained early in July, when a fairly heavy set was obtained, at the Deer Islands, amounting to between 400 and 500 spat per day per bag of shells. At the same time a set of 15 to 25 spat per day per bag of shells was obtained on the middle-ground reef, but not on the main reef. After this no further set took place in the bayou until the week following August 19, when the bags of shells on both reefs received a fairly heavy set. The graph (fig. 10) shows that at this time the salinity was rising gradually from 20 to about 24 parts per thousand.

No set was obtained on the Deer Islands Reef (fig. 11) until early in July, and this occurred on a rapidly rising salinity, which, during this time according to the samples taken, rose from about 14 to over 20 parts per thousand. These measurements are necessarily rough for there is much variation in such a body of water as West Bay where the effect of tides and winds is great. The salinity then remained at a slightly reduced level until the first of August when it started upward and by the end of August was close to 30 parts per thousand. Coinciding with this rise came a period of very heavy setting during which up to 3,000 spat were obtained daily per half bushel bag of shells. Figure 17 shows a sample of one of the clumps of shells bearing spat up to about two weeks old. Setting was still continuing when observations were discontinued.

In East Bay at Hanna Reef (fig. 12) only a few salinity determinations were made, but the results are in harmony with those above described. A period of setting took place early in May, extending over about two weeks, with its peak a few days earlier than that in the bayou. It may be assumed that at this time the salinity was high in East Bay as well as in the bayou. On the 23d it was down to 6 parts per thousand, even lower than that in the bayou. The infrequent determinations, as shown in the figure, indicate that after June 24, when the salinity was less than 2 parts per thousand, it rose to 12 parts per thousand on July 14 and possibly higher at the end of the month, as was the case in West Bay. (Fig. 11.) Samples of shells brought in on August 5 showed that a fair set had taken place during the preceding two weeks. On this date the salinity was 13 parts per thousand and on the next day was down to less than 10 parts per thousand, and no more setting occurred. Previous to the setting period the salinity was rising, and afterwards it was falling, but the salinity at the time of setting is unknown. Following this the salinity gradually rose to 18

parts per thousand on August 27 but no set was obtained at this time. On the other hand, at the same time the salinity in the bayou (fig. 10) and in West Bay (fig. 11) was between 24 and 30 parts per thousand, and setting was going on.

These records are suggestive of a marked correlation between the salinity of the water and the setting of oyster larvæ. The results obtained in Offatts Bayou are the most significant because the small size and relatively great depth of the channels prevent a rapid exchange of water, and variations in salinity are not as frequent or extreme as in either West Bay or East Bay. Consequently the daily samples of water tested gave results more representative of actual salinity conditions than in the case of the open bays. Although less accurate the records taken at the Deer Islands are also valuable for they are reasonably consistent in spite of the exposure of the bay to the effects of tides and winds. The results indicate that setting periods followed rises in salinity above approximately 20 parts per thousand, although it is certainly impossible to state an exact limit.

It has long been recognized that very low salinity is unfavorable to the production of seed oysters. A number of investigations on the Gulf coast have indicated the harmful effect of freshets on oyster larvæ. Moore and Pope (1910, p. 19) found that shells planted in the Bayou St. Denis in Louisiana "remained barren during the period in which the crevasse water (from the Mississippi River) was pouring over the beds, but after this was stopped and the water grew more salt a small set appeared on these shells * * *," although their figures of salinity during this period were between 13 and 14 parts per thousand. In Mississippi, Moore (1913) found heavy setting in water, the average salinity of which was about 22 parts per thousand, as contrasted to the observation of Moore and Pope (1910) that in one bay in Louisiana not far away there was a very slow set throughout the summer in water ranging in salinity up to about 13 parts per thousand, though the figures represent very few determinations. Churchill (1920) stated that oysters seem to thrive best in waters of salinity between 14 and 28 parts per thousand, and pointed out that the production of spat is inhibited by freshets. He considered larvæ to be extremely sensitive, particularly to cold and rain.

Conditions of salinity in the Gulf coast waters are entirely different from those in the waters of Long Island Sound where Prytherch (1929) has been able to predict the peak of setting to occur close to 15 days after the peak of spawning. This investigator found that in Milford Harbor, Conn., the salinity ranged from 25 to 28 parts per thousand. On the other hand the salinity in Galveston Bay during the spring and summer varied from less than 2 to nearly 30 parts per thousand. It is probably this variability which is largely responsible for the discrepancy between the spawning and setting times in Galveston Bay and those in Milford Harbor.

If, as appears to be the case, a salinity of above 20 parts per thousand was necessary in Galveston Bay before oyster larvæ would set, the question arises as to how this factor produced such an effect. The effect may have been indirect, due to the abundance of the organisms on which oyster larvæ feed which in turn may depend upon a certain salinity in order to attain maximum abundance. It is possible, though hardly probable, that oyster larvæ require water of a certain osmotic pressure in order to mature. It is also suggested that salinity as such is secondary in promoting setting and that the most important factor is some specific ion or salt in the water, a certain concentration of which is essential to the larvæ. Wheeler (1910), for example, found that in the vicinity of Beaufort, N. C., there was considerable difference between samples of water with respect to the relative percentage of some of

the salts. Analyses of Galveston Bay water showed similar and more striking variations in some of the salts. These data will be published at a later date. It is possible that oyster larvæ require a high concentration of some salt which in time of freshets is in concentration too low to permit the completion of larval development. If this is the case such a salt would be expected to be in high concentration in the pure Gulf water and lower concentration in the diluted bay water.

Prytherch [3] recently found that mature oyster larvæ may be caused to set by dissolving a small amount of a copper salt in the water. His evidence indicates that the copper in solution in the river waters emptying into Long Island Sound is instrumental in causing larvæ to set. The fresh water from the rivers, according to this worker, must be present in a high enough proportion to allow setting to take place; that is, a certain dilution, due to the river water, is conducive to setting. This is directly the opposite of the condition found to obtain in Galveston Bay, where setting appeared not to take place when the salinity was below about 20 parts per thousand. It may be that optimum conditions for setting are to be found when the sea water is diluted by land drainage only to a limited degree, and that when dilution is greater some necessary substance other than copper becomes reduced below the minimal required concentration. No conclusion can be drawn with respect to the actual cause of the phenomena observed in Galveston Bay, save that in some manner setting of oyster larvæ seems to be dependent either directly or indirectly upon salinity.

ABUNDANCE OF DIATOMS

The food of the oyster consists of the microscopic or semimicroscopic organisms which float in the water, particularly the diatoms and other algæ of comparable size and form. The richness of this plankton at different periods of the year determines in large measure the quality of the oysters, for without sufficient food oysters obviously can not fatten. It is important, therefore, to estimate the relative abundance of diatoms in the water near oyster grounds.

Plankton collections were made in the vicinity of Galveston during the spring and summer months, and these results show an interesting fluctuation in the relative abundance of diatoms during this time. Collections were made with a plankton net of No. 20 bolting silk, and hauls were made at the surface of the water. While the collections were made primarily for obtaining oyster larvæ, they served as well foı diatoms. Samples were taken only infrequently during April and the first part of May, but after this they were taken almost every day.

The relative abundance of diatoms was estimated as in the case of oyster larvæ. Numbers from 0 to 6 were used to designate the relative number of diatoms from none to the maximum ever taken. The method is not strictly quantitative but serves well enough to show roughly the seasonal variation in abundance of diatoms. The numbers representing abundance were defined as follows: 0, diatoms totally absent, although this was never the case, for in every collection there would be at least one or two diatoms; 1, very few diatoms, representing scarcely enough to form a coating on the bottom of the bottle; 2, few; 3, fair number; 4, many; 5, very many; and 6, extremely abundant, so that the plankton net became clogged and the sample bottle was as full as possible of diatoms. The gradations in between the extremes are largely arbitrary, but since all estimates were made over a period of a few days, while the last of the samples were being taken, and by the author only, they represent a reasonable degree of accuracy.

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[3] Unpublished manuscript.

In Figure 18 all of these data are presented graphically. There are two main series, the samples from Offatts Bayou and those from West Bay. In the former each point represents the average of three samples taken at the three places designated in Figure 5 (stations 1, 2, and 3). This average is a fair estimate of the abundance of diatoms in the bayou, for the places where collections were made include not only the water near the mouth which is changed frequently by tides but also that farther up in the bayou where the water is only slowly exchanged. In the case of the points representing West Bay collections each point is the average of three determinations; two from near the Deer Islands and one from a short distance out in West Bay from the mouth of the bayou. (Fig. 4, stations 4, 5, and 6.) These points do not give as complete an idea of the abundance of diatoms in West Bay as do those referring to the bayou, for West Bay is much larger. In spite of this fact, however, it will be observed (fig. 18) that there is a striking parallel between the records in the two places.

Another series of samples is also represented in the figure, referring to East Bay near Hanna Reef. Samples were taken only infrequently, and many of those taken are not included because the water was muddy and clogged the net, making the samples of doubtful value. However, these few points are distinctly in agreement with those of the other two series, suggesting that the records constitute a fair estimate of the diatom content of Galveston Bay as a whole.

The most striking characteristic of these records (fig. 18), when minor fluctuations be overlooked, is the gradual reduction in abundance of diatoms in the water from the end of March, when the first samples were taken, to the end of August, when sampling was discontinued. In the former case the water was so full of diatoms that a haul had to be shorter than the standard time, due to clogging of the net. Toward the end of July and during August most of the samples contained little else save oyster larvæ. In most cases at this time very careful microscopic examination was necessary in order to find one or two diatoms. These samples were designated as halfway between none and very few and actually represent the virtual absence of diatoms of the sizes taken by the net.

Comparison of the graph of diatom abundance with those of temperature (fig. 9) and salinity (fig. 10) is of interest. The temperature rose rapidly toward the end of March to over 25° C. and after this time diatoms became rapidly less abundant. The diatom records for the end of April and beginning of May are too scattered to be particularly significant, but the few samples during this period showed extremely few diatoms in the water. The salinity during March, April, and half of May was in the neighborhood of 20 parts per thousand. However, following May 20 the salinity dropped quickly from 20 to about 14 parts per thousand, due to increase in river discharge. This was accompanied by a drop of a few degrees in temperature. At the same time there was a great increase in the diatom content of the surface water which lasted for about 10 days, and then abruptly the diatoms disappeared.

The variations in the average temperature of bayou water (fig. 9) after the middle of May appear to bear a definite relationship to the abundance of diatoms in the samples taken in this place. In nearly every case, between this time and late in the summer, whenever there was a marked fall in water temperature there was a rise in abundance of diatoms collected. When the temperature rose again the diatoms taken became less abundant. Even minor variations in temperature were accompanied by fluctuations in the abundance of diatoms taken. Whether the temperature variation is itself responsible for differences in the abundance of diatoms is not clear.

It is possible that the diatoms sink into deep water when the water is warm and rise to the surface when the water is cooler; or else wind which cools the water also

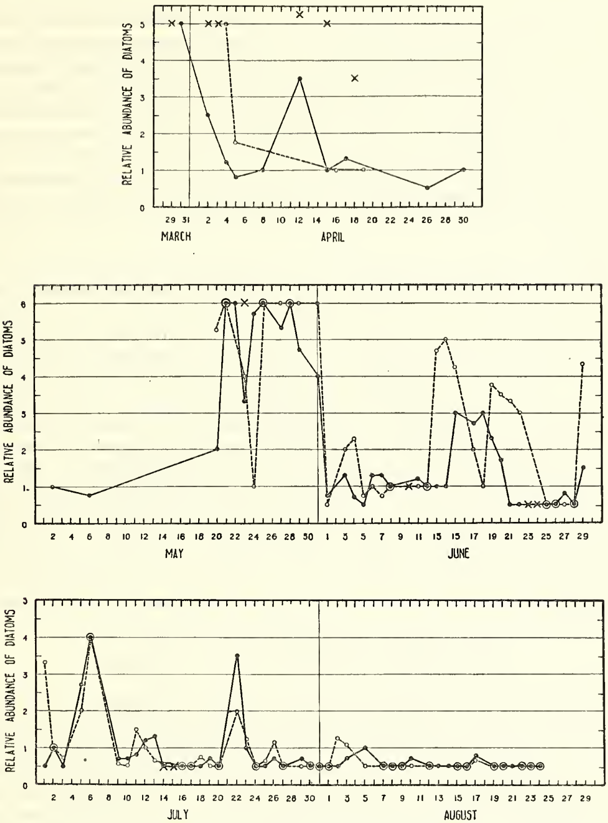

FIGURE 18.—Charts showing the relative abundance of diatoms, taken with plankton net of No. 20 bolting silk, in Galveston Bay. Solid points represent collections in Offatts Bayou, each point being the average of three or more samples. Circles refer to collections in West Bay near Deer Islands, representing usually three samples in East Bay, near Hanna Reef, are designated by X's. Abundance of diatoms was roughly estimated as follows: 0, none (although in no case were they considered to be absolutely absent); 1, very few; 2, few; 3, fair number; 4, many; 5, very many; 6, extremely abundant. The figures are only rough estimates but clearly show certain fluctuations, especially the disappearance of diatoms toward the end of the summer

stirs up the diatoms which may have settled to the bottom; that is, these minor variations may have been due to the method of sampling, for the net was effective only for the surface 12 or 15 inches of water. It is this surface water, however, which is

of particular significance with regard to oysters in most of the Gulf of Mexico waters, since most oysters occur at approximately the low-tide level and few are found in deeper water.

Whatever may be the significance of the correlation between temperature fluctuations and the abundance of diatoms at the surface, the graphs (figs. 8 and 19) show distinctly the gradual disappearance of diatoms between March and August. This is entirely in harmony with the well-known seasonal variation in diatom growth. Steuer (1903) called attention to the fact that while in northern waters there are two maxima of diatom abundance, one in spring and one in the fall, in more southern waters the two maxima encroach more and more upon the winter months, thus tending to fuse together in warm regions to form a single winter maximum. This condition was found in the Adriatic. A secondary maximum was found to occur in June and July. Fish (1925) found essentially the same condition to obtain in Buzzards Bay.

Since this variation is a function of temperature, and since the warmer the water the greater the tendency to concentrate the maximum into the winter months, it would be expected that in the very warm water of Galveston Bay the maximum would be of relatively short duration, perhaps in mid or late winter, depending upon the time of minimum temperature. It would be of considerable importance in reaching a complete understanding of the differences between oysters of the North Atlantic coast and those of the South Atlantic and Gulf coasts to obtain systematic diatom collections throughout the year. It may well be that the short season during which oysters in the southern waters are fat or prime is due as much to a short period during which sufficient food is available as to the long spawning season. The observation of Battle (1892) on oysters in South Carolina waters is of significance in this respect. He wrote (p. 329): "As a rule the oysters do not attain their best condition in South Carolina until late in the winter and early in the spring." Yet the spawning season there, as in Texas, probably ends in late fall. It is very probable that the oysters do not become prime until relatively late because of the lack of food in fall and early winter, and that the period of maximum "fatness" of the oysters corresponds closely with the period of maximum abundance of diatoms.

USE OF WIRE BAGS OF SHELLS AS CULTCH

In South Atlantic and Gulf waters one of the major difficulties in obtaining seed oysters is due to the fact that silt and slime soon cover the cultch after it is placed in the water. As has been discussed in the preceding pages, the setting periods in Galveston Bay were scattered and of short duration, although setting might be expected at times during at least six months of the year. Had shells been placed in the water at the middle of April when a set was expected, the shells would have become silted and their value as cultch in this manner reduced before any setting took place. For this reason the simple method of spreading shells on suitable bottom is inadequate especially when the setting does not occur soon after the planting of the shells. One aim of the present investigation was to determine whether the method of using wire bags of shells as cultch is suitable in such a body of water as Galveston Bay. A complete account of experiments with these bags on the Atlantic coast has recently been published by Galtsoff, Prytherch, and McMillin (1930).

As has been described, the set obtained on shells in such bags in Galveston Bay was highly satisfactory. Table 3 shows the number of spat per bag of shells obtained

at different places and during different periods of time. The heaviest set was obtained at the Deer Islands in August when the inside surfaces of the shells in each bag (one-half bushel) bore nearly 20,000 spat. The outer surfaces of the shells probably received as heavy a set, so it may be said that the set amounted to 40,000 spat per half-bushel bag of shells. In Figure 17 is a photograph of a clump of shells from one of these bags showing the great abundance of young spat.

In some cases the spat are too abundant for they would tend to grow into coon oysters unless broken apart while still relatively small. If left in the water longer even more would set on the same shells, resulting in considerable crowding. Shells which are merely spread on a reef as cultch can not readily be removed when the proper amount of set is obtained, but the bags may be removed when desired and transferred to beds in deeper water for growth where little or no further setting occurs. Also, after the shells in bags have become slimy and bear no set, the bags may easily be taken up and left in the sunshine for a few days, and then put back into the water as clean cultch on which larvæ will set. In this manner seed may be collected in desired abundance for planting on private grounds or for developing new public grounds.

TABLE 3.—*Number of spat on the inside surfaces of shells planted in Galveston Bay, 1929*

Date planted	Date removed	Place	Spat per half bushel of shells	Date planted	Date removed	Place	Spat per half bushel of shells
May 6	May 20	Bayou, main reef	975	June 25	July 10	Bayou, middle ground	67
Apr. 18	May 23	Hanna reef	212	Do	July 18	Deer Island	2,700
May 20	May 31	Bayou, middle ground	120	July 15	Aug. 6	Hanna Reef	1,800
May 28	June 25	Bayou, main reef	31	Aug. 3	Aug. 14	Deer Island	15,000
May 31	do	Deer Island	22	Do	Aug. 22	do	19,000
June 25	July 9	do	1,270	Aug. 20	Aug. 27	Bayou, main reef	(1)

1 Spat present, but not counted.

This method may be employed as an economical means of developing oyster ground in places not near the natural reefs. The removal of common coon oysters from reefs as seed is also advisable but this method involves more labor in culling and transportation than that above described. More recently the use of cement-coated egg-crate partitions (Prytherch, 1930) has been found to be highly efficient as a method of collecting seed oysters. This method might well be employed on the Texas coast. Such modern methods of oyster culture if applied extensively in the coast waters of Texas should increase the production of oysters tremendously. The survey by Galtsoff [4] in 1925 showed that the coastal waters comprise large areas which appear to be suitable for oyster culture.

SUMMARY

(1) The spawning season of oysters in Galveston Bay in 1929 was observed to begin at the end of March. At the end of August larvæ were still in the water and the oysters still milky, indicating a spawning season of at least six months.

(2) Spawning started when the average daily water temperature in Offatts Bayou was about 25° C. When 20° C. was reached the oysters were just beginning to develop mature eggs and sperms, causing them to appear milky.

4 Unpublished manuscript in the files of the Bureau of Fisheries.

(3) Thermograph records of water temperature in the bayou show that at the end of February the winter temperature was 14° to 15° C., while during the spring and summer it rose to between 30° and 33° C.

(4) Because of increased river discharge in spring and early summer the salinity of the water in Galveston Bay remained low for a considerable time. In early spring the salinity in the bayou was 22 to 24 parts per thousand, while early in June it was down to 7 parts per thousand. At the same time in West Bay it was only 4 parts per thousand. In East Bay late in June it was below 2 parts per thousand. During July and August the salinity rose to between 20 and 30 parts per thousand.

(5) The characteristic pH of the water in Galveston Bay was between 8 and 8.4, fluctuating between these levels. In August in the bayou it rose to 8.9.

(6) Setting was irregular and took place during short, isolated periods. The first spat were not obtained until a month and a half after spawning started.

(7) In Offatts Bayou two chief setting periods occurred, one at the middle of May, and the other beginning at the end of August. In addition two very light sets were obtained at one place in the bayou; at the end of May and at the beginning of July, respectively.

(8) In West Bay at the Deer Islands two setting periods were observed; a short one early in July, and a more prolonged one beginning at the first of August. At the latter time setting was very heavy and up to 3,500 spat were obtained daily per bag of shells.

(9) On Hanna Reef, East Bay, a light set was obtained at the beginning of May and a fairly heavy one at the end of July and first part of August.

(10) The setting periods appear to have been correlated with periods of high salinity, suggesting that in some manner the larvæ depend, either directly or secondarily, upon a salinity above about 20 parts per thousand, in order to develop to the setting stage.

(11) Most of the larvæ taken in the collections were in the straight-hinge stage, with the exception of short periods, until August when many umbo larvæ were taken. It is probable that setting was not more continuous because early in the season few reached the setting stage.

(12) Of 252 adult oysters from different reefs only 51 were males and 178 were females. The remaining 23 specimens were either too completely spawned out or immature to permit ready determination of sex.

(13) Diatoms in the surface plankton collections were most abundant in early spring and slowly decreased in numbers taken so that in July and August the water was almost free of them. It was observed that during periods of low temperature of the water more diatoms were taken than during times of high temperature. This was the case for temperature changes occurring over a few days as well as over the entire period during which collections were made.

(14) Use of wire bags of shells as cultch was tested in Galveston Bay waters and found to be highly satisfactory as a means of collecting spat for developing oyster grounds.

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STUDIES ON THE OYSTER DRILL (*UROSALPINX CINEREA*, SAY)[1]

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CONTENTS

INTRODUCTION

Although the common oyster drill (*Urosalpinx cinerea*)[2] feeds on many mollusks its economic importance is due to the fact that it destroys a great many oysters. At times the damage wrought has been very great. In Long Island Sound (Rowe, 1894) and in New Jersey (Nelson, 1923) the loss from this species amounts annually to over a million dollars, and recently it has been reported as causing great destruction to the oyster beds of England (Orton and Winckworth, 1928).

In spite of the above facts and although several investigators had called attention to the pressing need of more information on the subject no detailed study had ever been made of the species (Rathbun, 1892; Collins, 1890; Townsend, 1893; Hall, 1894; Moore, 1897, 1911; Churchill, 1921), and the only available data are those collected by investigators during their work on the oyster and Pope's (1910–1911) unpublished manuscript on the oyster drill in New England.

This paucity of information on the life history of the drill and its invasion of Hampton Roads, Va., brought the question to the immediate attention of the United States Bureau of Fisheries. The situation at Hampton Roads was alarming. Planters claimed to have lost as much as 90 per cent of their oysters. Since this is an important oyster producing area the continued invasion demanded some remedy and so in 1926 the author was commissioned to make a detailed study of the species. The work was carried on in a temporary laboratory at the United States Public Health Quarantine

[1] Approved for publication Jan. 16, 1931.

[2] The terms "drill" and "borer" have been used to describe other gastropods besides *Urosalpinx cinerea* but this report will deal only with this species. Many older reports simply use the term "drill" (Ryder, 1883; Rathbun, 1893; Hall, 1894; Rowe, 1894; Moore, 1897; 1898, 1911; Swift, 1898) and do not give the species, so that it is impossible to determine exactly to which of the many "drilling" gastropods the author is referring.

Station on Craney Island, Norfolk, Va.,[3] and at the United States Fisheries Biological Station, Beaufort, N. C.

The aims of the research were to study the life history, habits, and migrations of the oyster drill and to make recommendations of measures that would either eliminate the animal or so reduce its numbers as to make it a negligible factor in the oyster industry.

Since it was impossible to make a study of the complete life history of the drill, the work was necessarily limited to the following fields: A survey was made in Hampton Roads in which salinity, temperature, pH, and character of bottom were studied; and the salinity data were corroborated by a study of the salinity death point in the laboratory. Since in a study aiming at the control of a species it is of prime importance to know the extent, direction, and periodicity of its migrations, the movements of tagged drills were studied. Other problems studied were: The effect of temperature on the activities of the animal, its feeding and breeding habits, and its tropistic behavior. Whenever possible field observations were checked by laboratory experiments under controlled conditions.

NATURAL HISTORY OF UROSALPINX CINEREA, SAY

DESCRIPTION OF THE SPECIES

The fusiform, longitudinally ribbed, and spirally striated shell of *Urosalpinx cinerea* is usually greyish yellow, light brown, or occasionally white in color. The aperture varies from light flesh to dark salmon, chocolate, or purple and possesses a comparatively short canal. The outer lip of the aperture is dentate; the operculum is semicordate with its nucleus at the outer edge or a little below the middle. In Chesapeake Bay the shells generally range between 21 to 25 millimeters in length (Federighi, 1930), and as in other gastropods (Tryon, 1880; Cooke, 1895; Dimon, 1905; Pelseneer, 1906) the females attain greater length than the males. The largest female, found in Chesapeake Bay, measured 33 millimeters in length, the largest male 29 millimeters. Aside from this rather general characteristic there is no distinguishing feature between the sexes.

The body of the animal is small; the foot scarcely covering the aperture and only very little dilated at the front angles. It is cream-colored, margined with lemon color beneath, and punctuated with light drab above. The siphon extends just beyond the canal. The head is scarcely protruded with tentacles united at the origin, and at the filamentous and contractile outer third of the tentacles are located the black eyes.

RANGE AND OCCURRENCE

Urosalpinx cinerea, the oyster drill, is commonly reported as inhabiting the marine and brackish waters of the Atlantic coast from Maine to Florida (Verrill, 1873; Tryon, 1880; Churchill, 1921). It has been collected in San Francisco Bay, carried there in the shipment of eastern oysters (Rathbun, 1892; Townsend, 1893; Dall, 1907–1909); in Bermuda (Arey and Crozier, 1919); only sparingly on the Gulf coast (Moore, 1898, 1906; Ruge, 1898); and recently (Orton, 1927; Orton and Winckworth, 1928) it has been reported from England.

The Eastern Shore of Virginia has been infested with this gastropod for many years (Uhler, 1879–80; Ryder, 1883; Henderson and Bartsch, 1915), and in 1908

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[3] The author wishes here to express his thanks for the help and hospitality shown him by the U. S. Public Health Service and especially to Dr. H. E. Hasseltine and Dr. C. E. Waller, also to all others who contributed in making the work possible.

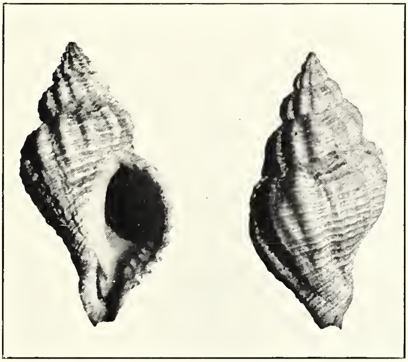

Figure 1.—The common oyster drill (*Urosalpinx cinerea*). Actual size, 1⅛ by ⅝ inches

the Virginia Fisheries Commission (Lee, 1909) wrote: "Borers are to be found only on our seaside, but in less alarming quantities than in other waters of the coast." Recently the important oyster beds of lower Chesapeake Bay have suffered from this pest to such an extent as to threaten the whole industry. This area is so large

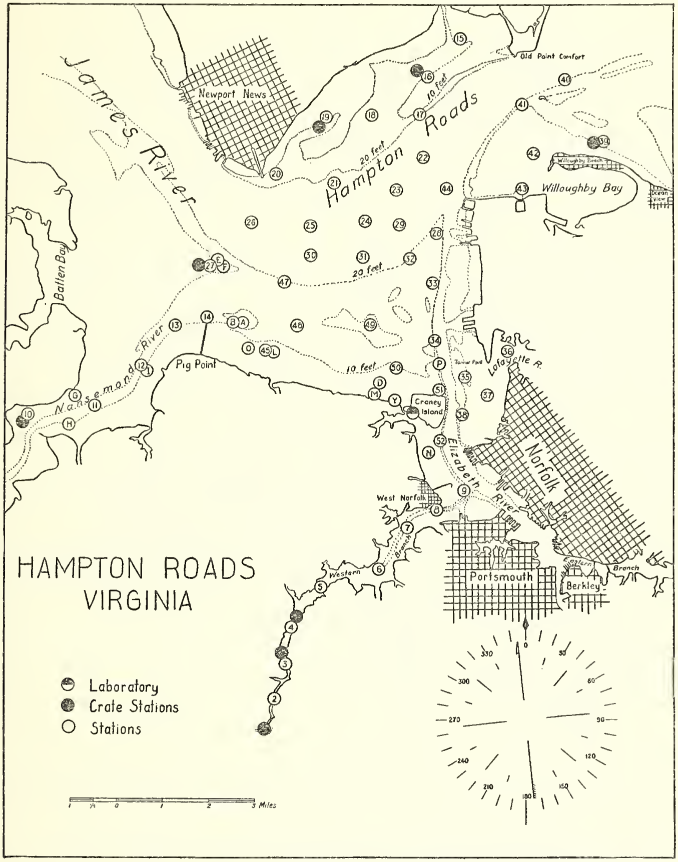

FIGURE 2.—Chart showing Hampton Roads and tributaries. Stations are indicated by circles

that it was impracticable to attempt a complete survey of the region. The survey herein reported was restricted to Hampton Roads and its tributaries. Stations as shown in Figure 2 were laid out and observations were made on the salinity, pH, character of the bottom, depth, temperature, the number of *Urosalpinx* present and,

wherever oyster beds existed, the number of perforated shells among a definite number of oysters taken at random. The study was made in June, 1927, so as to avoid the low salinities which obtain during the spring months. (See salinity chart,

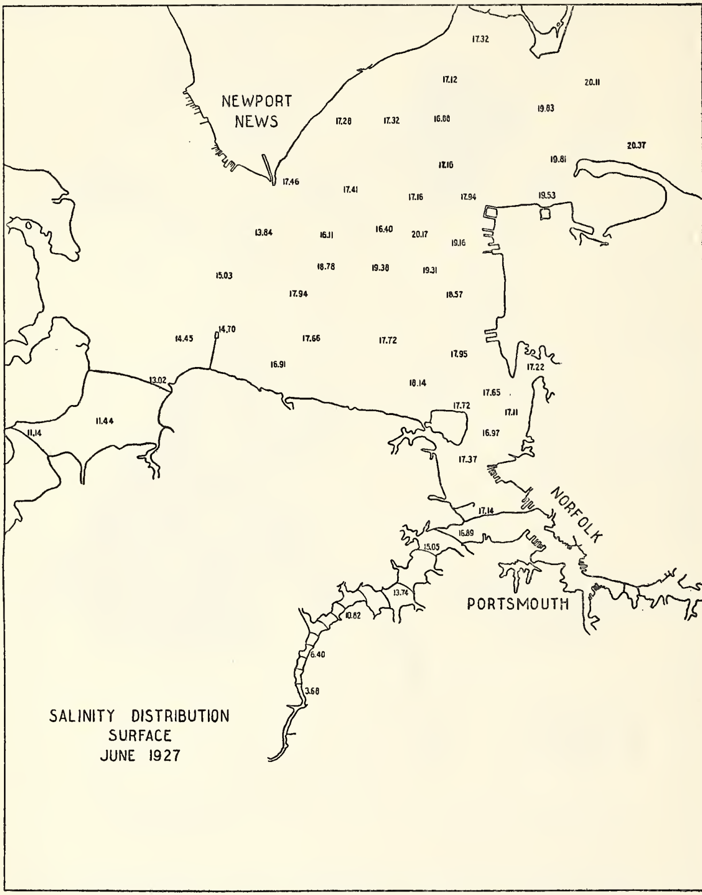

FIGURE 3.—Chart showing distribution of surface salinities over Hampton Roads for June, 1927

fig. 3.) In order to ascertain the relative number of drills over the various beds a small oyster dredge was dragged over the bottom for 5 minutes behind a slow moving motor boat. The following table shows the results of the survey:

TABLE 1.—*The relation between the number of drills and various environmental factors*

[Survey made at Hampton Roads during June, 1927. See fig. 2]

Station	Drills present in a unit area		Salinity in parts per mille	pH	Depth in feet	Character of bed	Station	Drills present in a unit area		Salinity in parts per mille	pH	Depth in feet	Character of bed
	Alive	Dead						Alive	Dead				
	Number	*Number*						*Number*	*Number*				
A	1	1	17.00	7.8	12	Natural.	S	3	2	18.00	7.8	10	Natural.
B	3		17.00	7.8	8	Do.	T	2		17.25	8.0	4	Planted.
D		1	18.00	7.9	7	Do.	U	13	3	20.00	8.4	14	Do.
E	8	4	15.00	8.0	10	Do.	W	18	2	17.00	8.2	9	Do.
F	8		15.50	8.1	12	Do.	X	13		17.00	8.0	8	Do.
G			11.50	8.0	5	Do.	Z	8	5	17.25	8.3	12	Do.
H			11.50	8.0	5	Do.	AA	3	4	19.50	8.3	7	Do.
I		1	13.00	8.0	2	Do.	BB	5	6	19.30	8.2	6	Do.
K			16.50	8.0	5	Planted.	16	17	5	17.00	8.2	10	Do.
L	2	1	17.00	8.0	8	Do.	18	14	2	17.25	8.0	9	Do.
O	3		17.00	8.0	8	Do.	19	16	4	17.25	8.1	11	Do.
P	2	1	17.50	7.8	12	Natural.	27	4	2	15.25	7.9	12	Natural.
Q	16	2	19.25	8.2	15	Planted.	45	17	1	17.00	7.8	10	Planted.
R	2	1	17.00	7.9	9½	Natural.							

The drill is found over the whole area of Hampton Roads, being more abundant on the planted areas than on the natural rock, a condition that is explained by the absence of any migratory habits. Salinity below 15 parts per mille, muddy bottoms, clear sands, and depths greater than 25 feet are factors unfavorable for its growth and multiplication. At Beaufort it flourishes and reproduces at average summer salinities of 35 parts per mille. In Hampton Roads the snail does not occur above the low-water mark, but in Connecticut and in North Carolina it is found on beds exposed at low water.

SALINITY AND DISTRIBUTION

Although many investigators have studied the adaptation of organisms to varying salinities, the mechanism for this adaptation, the relation between the environmental salinity and the salt content of the blood, the importance of salinity as a barrier to the multiplication and distribution of a species, and the lethal salinities for several animals (see Duval, 1925, for complete bibliography); no attempt, so far as the author knows, has been made to correlate the death-point salinity with the salinity of the environmental waters. During these studies certain data were collected on the resistance of *Urosalpinx* to low salinities. Three sets of data are available, one gives the results of a preliminary experiment made at Norfolk during the summer of 1927; the other two sets of data were collected at Beaufort, N. C. The latter are more complete and permit of more accurate analysis. The conclusions from these observations, already published elsewhere (Federighi, 1931), are given in the following paragraphs.

Moore (1911) stated that in Delaware Bay the oyster drill does not thrive at specific gravities below 1.012 to 1.013 (salinity: 15.50–17 parts per mille). In 1923 Nelson gave the minimum salinity for the survival and reproduction of this gastropod in New Jersey as 18.33 parts per mille—a figure that has recently (1928) been lowered to 15 parts per mille (private communication). At Hampton Roads, according to the author's observation made in June, 1927, the snail does not normally inhabit waters of salinities below 15 parts per mille. What the upper salinity limit may be is shown by observations made at Beaufort, N. C., where drills were found living and reproducing in areas where the summer salinities run as high as 37 parts per mille for several days (summer, 1928).

During the summer of 1927 preliminary experiments to determine the lower lethal salinity were made at Norfolk, Va., on snails collected from Hampton Roads. The animals used were taken from two localities, the June salinities of which averaged, respectively, 15 and 20 parts per mille. They were kept in the laboratory for about six weeks where the salinity was taken daily and where it never rose over 20 parts per mille. The two sets of drills were mixed and specimens for experimentation taken at random.

The procedure was as follows: Salinities between 5 and 17 parts per mille at intervals of approximately 2 parts per mille, obtained by diluting sea water with distilled water were used. The animals, 20 at each salinity, were immersed in the water and kept submerged by means of a wire screen stretched below the surface. The jars (of approximately 2 liters capacity) were kept loosely covered to prevent excessive evaporation, and the water was oxygenated twice daily by vigorous stirring. That this was sufficient is shown by the fact that drills will live in jars of sea water for several months without change of water or oxygenation. Temperature, salinity, and pH were taken daily and the condition of the animal noted. The criterion of death was whether or not the mantle would respond to a needle prick. When an animal was found that did not respond to this stimulus it was removed from the experimental jar and placed in running sea water to determine whether or not it would recover. In every case the animal would by putrefying within a few days give conclusive evidence that water of that salinity was lethal to the specimen. Death was always preceded by the animal becoming unattached, and at the lower salinities the animal swelled and protruded from the shell before dying, owing undoubtedly to the difference in osmotic pressure. The animals were kept under observation for 10 days, at the end of which time the surviving drills were returned to running sea water and their activity noted. Three different sets of observations comprise these experiments. (Table 2.)

TABLE 2.—*Effects of varying salinity on Urosalpinx cinerea, from Hampton Roads, summer of 1927*

Items	Experiments		
	No. 1	No. 2	No. 3
Salinity at which drills were killed	10.12	12.52	11.35
Percentage of deaths after 10 days	90	75	90
Salinity at which drills survived	12.26	15.05	13.91
Percentage of survival after 10 days	95	90	85
Percentage of deaths in control	10	5	15
Average temperature for period (°C.)	26	26	24
pH for period	8–8.1	8–8.2	7.9–8.2

During the summer of 1928 experiments, similar to those mentioned above, were made on drills collected at Beaufort, N. C., where the summer water salinity rose as high as 37 parts per mille and remained well over 30 for the entire season. The following modifications were made in the procedure as given for the Norfolk experiments: (1) The water was oxygenated by bubbling a continuous stream of air through it; (2) instead of using the mantle as a criterion of death, the tip of the siphon was employed for this purpose. The results, which are preliminary, are given in Table 3. The pH values, which are rather high, remained with but small variations between 8.4 and 8.8. The continuous stream of air through the sea water brought about a small increase in the pH during the first 24 hours, after which it

remained constant. For this reason the animals were not introduced into the jars until the second day.

TABLE 3.—*Effects of varying salinity on Urosalpinx cinerea from Beaufort, N. C., summer, 1928*

Items	Experiments		
	No. 1a	No. 2a	No. 3a
Salinity at which 50 per cent of drills were killed	12.81	14.45	16.00
Percentage of deaths after 10 days	95	90	70
Salinity at which at least 85 per cent of drills survived	16.89	16.22	17.43
Percentage of survival after 10 days	90	85	100
Percentage of deaths in control	10	10	15
Average temperature for period (°C.)	26	26	24
pH for period	8.4–8.8	8.6–8.8	8.4–8.8

Before giving the more detailed Beaufort experiments made during the spring and summer of 1929 certain conclusions derived from the above results should be given. In order to do so a word of explanation is needed concerning lines 1 and 3 in Tables 2 and 3. Line 1 gives the experimental salinity at which at least 50 per cent of the drills died; line 3 gives the next highest salinity in the experiment at which not more than 10 to 15 per cent of the animals died. The author has arbitrarily taken the mean of the figures in lines 1 and 3 and called this the salinity death point. It is believed that the nature of the experiments and results justify such a procedure. This method gives as close an approximation to the salinity death point as can be gotten even by reducing the intervals between the salinities used.

If the results given in Tables 2 and 3 are analyzed according to the method just indicated the results obtained are these: *Urosalpinx cinerea* collected from Hampton Roads in two regions having respectively the following average summer salinities, 15 and 20 parts per mille, have a salinity death point of approximately 12.5 parts per mille. On the other hand animals collected from Beaufort where the summer salinity is well over 30 parts per mille have a higher salinity death point; that is, 15.6 parts per mille.

The discrepancy between the death-point salinity and the salinity below which drills do not occur in the field at Hampton Roads can easily be explained after a study of the variations in the salinity of this region occurring throughout the year. During March, April, and early May (1927) the salinity at Craney Island dropped below 12 parts per mille for several days, although during the summer and winter months the salinity averaged over 17 parts per mille (Federighi, 1930a). Thus, although the survey during June, 1927, showed that the drills are not found below a salinity of 15 parts per mille, this is not the minimum salinity for survival, since during the spring the salinities of these areas fall as low as 12 parts per mille—a figure sufficiently close to the experimentally determined salinity death point (12.5 parts per mille).

During the summer of 1929 detailed experiments were conducted to check the observations made in 1927 and 1928. For this purpose a total of 3,290 animals were used at salinities ranging from 8 to 35 parts per mille. Of this total number 150 drills were from Hampton Roads (Series VIII), the remainder (3,150) were collected at Beaufort. The procedure was essentially the same as that employed for the preliminary Beaufort experiments. In these studies 50 drills were placed in each jar which contained 2 gallons of sea water of the desired salinity. The water was kept

oxygenated by running a continuous stream of air through it. Each day the drills were examined, and the number of dead in each of the jars noted. In all, 8 series of experiments were run. The detailed procedure for each series is given in the following paragraphs.

In Series I, II, III, and IV the salinities used ranged from 9 to 34 parts per mille at intervals of less than 2 parts per mille. In all, these involved the use of 1,350 animals. The results may be summarized as follows: Below a salinity of 15 parts per mille over 50 per cent of the drills were killed. The optimum range seemed to be between 17 to 22 parts per mille where the number of deaths remained less than 15 per cent. Above a salinity of 23 parts per mille the number of deaths again increased to over 50 per cent. These results seemed peculiar in view of the fact that at Beaufort where these drills were collected the salinity only rarely fell below 20 parts per mille and usually remained above 30 parts per mille. This indicated that other factors besides salinity must be involved in the deaths at salinities above 23 parts per mille.

One of the factors that might contribute to the death of the drills at salinities above 23 parts per mille is the rapid reproduction of plankton and its subsequent death and putrefaction. Below 23 the low salinity might act as a retarding factor in the reproduction of the plankton. Thus it might be that the putrefaction of a large number of plankton which might obtain at the higher and more nearly normal salinities might so foul the water as to kill the drills.

In order to test this, two types of experiments were run. The first involved the use of sterile glassware, boiled sea water, and drills washed in sterile sea water. Everything was done to keep the initial plankton count to a minimum. If the putrefaction of the plankton were a contributing factor to the death of the drills at the higher salinities, we should find that with the above precautions the number of deaths at salinities above 23 parts per mille would be greatly reduced. Such indeed was the case. In Series V (see Table 4) where this was done, deaths to number of 50 per cent occurred only at salinities below 15 parts per mille. At the higher salinities the percentage of deaths only rarely exceeded 15 per cent.

Another way to test the above assumption is to change the sea water (of the proper salinity) in each jar daily. In Series VI and VII (1,200 animals) this was done, and again only salinities below 15 parts per mille were fatal. (Table 4.)

The observations made during 1929 on the drills from Hampton Roads showed that the lower limit for survival of the snail is approximately 12.5 parts per mille, a result that is similar to that one obtained during the summer of 1927. (Table 2.)

TABLE 4.—*Effects of varying salinity on Urosalpinx cinerea from Beaufort, N. C., and Hampton Roads, Va., summer of 1929*

Items	Experiment No.—			
	V	VI	VII	VIII
Salinity at which drills were killed (p. p. m.)	15.25	16.64	16.51	10.63
Percentage of deaths after 8 days	94	92	76	100
Salinity at which drills survived (p. p. m.)	18.25	18.87	19.93	12.79
Percentage of survival after 8 days	94	82	86	75
Percentage of deaths in control	2	12	12	0
Average temperature for period (° C.)	23	23	22	25
pH for period	8.6	8.5	8.6	7.9

The preceding data show that the salinity death point of *Urosalpinx cinerea* is influenced to a great extent by the evironmental salinity. Snails collected at the Norfolk Point localities having salinities of approximately 15 and 20 parts per mille show lethal salinities of approximately 12.5 (Table 2) and 11.7 parts per mille (Experiment No. VIII, Table 4). On the other hand snails collected at Beaufort with an environmental salinity of approximately that of sea water (over 30 parts per mille) for most of the year, show a lethal salinity of 15.6 (Table 3) and 17.6 parts per mille (Experiments V, VI, and VII, Table 4).

In this connection it is interesting to draw attention to one fact which these results bring out. The extent of adaptability, or the salinity factor of safety, becomes smaller as the animal becomes adjusted to lower salinities. Thus at Hampton Roads a drop of from 8 to 9 parts per mille (at the maximum, from 20 to 12) was fatal, while at Beaufort a decrease of over 15 parts per mille in the salinity of the waters was necessary for death (from 30 to approximately 16). The adaptation to lower salinity seems to bring about a reduction of the salinity safety factor. This lower factor of safety in an animal which has become adapted to lower salinities may become of biological importance in its distribution. For instance, heavy rains in the area drained by the Elizabeth, Nansemond, and James Rivers might reduce the salinity of the Hampton Roads region sufficiently so that *Urosalpinx cinerea* infesting oyster beds in this locality would be killed in great numbers.

CREEPING AND MIGRATIONS

In the majority of gastropods locomotion is dependent on the formation of successive pedal waves (Parker, 1911, 1914); and according to Parker (1911, 1914) and Olmsted (1917) the pedal wave is an area lifted from the substratum in which movement takes place, the remainder of the foot being stationary. Other investigators have claimed that the wave is an area of convexity (von Uexküll,1909; van Rijnberk, 1918–19; ten Cate, 1923). Some few gastropods have also been described as showing no pedal waves during locomotion. Parker (1911) and Crozier (1919) believe that where no cilia are present this type of locomotion is due to an "arhythmic" type of pedal waves; and Dubois and Vlès (1907) have shown that even though the pedal surface is ciliated, locomotion depends on muscular activity alone. More recently Copeland (1919, 1922) has maintained that locomotion due to cilia does obtain among gastropods (Alectrion and Polynices), a conclusion that does not seem to be altogether proven by his results. The mechanism by which the pedal wave is produced has been studied, and several theories have been brought forth; but the subject does not properly belong here. Anyone interested in it will find a complete bibliography in van Rijnberk's paper (1918–19).

In *Urosalpinx cinerea* no pedal waves can be demonstrated during locomotion. It moves by a smooth, gliding motion comparable to that of *Nassa obsoleta* (Parker, 1911; Copeland, 1919) and *Conus agassizii* (Crozier, 1919). Furthermore the pedal surface is covered with cilia whose effective stroke is backward, leading one to suppose that locomotion is due to their activity.

A study of the pedal surface both moving and at rest gave some interesting results. At rest, the animal is attached to the substratum by means of the posterior part of the foot. When movement is to take place, the anterior margin of the foot is thrust forward and attached. Until this part of the foot is in contact with the substratum no translatory movement can occur. Cessation of locomotion occurs only after the anterior margin has been lifted from the substratum. Thus there is

a close connection between locomotion and the anterior margin of the foot. On close examination of this area it was found by the author to be divided by a transverse depression forming a pair of lips at the front of the pedal surface. Anterior to this depression were seen small, irregular, transverse waves, that were too rapid to count and to examine carefully, and that never crossed the indentation. These waves had also been observed by Parker (1911) and Copeland (1919) in *Alectrion*.

The animal creeps forward at an average rate of 2.6–2.8 centimeters per minute at 26.5° C.—a relatively slow rate—and as in many gastropods reversal of progression does not occur. Adhesion depends entirely on the secretion of slime, as is shown by the absence of areas of concavity that are necessary if suction plays any part in adhesion.

Microscopic study of the pedal surface showed that the whole of it is covered with cilia, and by the use of carmine it was demonstrated that their effective stroke is backward. Isolated pieces of the pedal surface showed beating cilia after 24 hours. Because the pedal surface is small, it was impossible to repeat Copeland's (1919) observations on *Alectrion* in which, by allowing the animal to creep along the surface of the water, he was able to show that the cilia beat only during locomotion.

In the study of the natural history of any animal it is important to know something about its migrations. If control measures are to be devised this question assumes even greater significance since it is so closely related to the distribution of the animal. For this reason the migrations of the drill were studied at Hampton Roads and at Beaufort. As Gowanloch (1927) found, gastropods are not easily marked. After many attempts the following methods were used: (1) Coloring the shell with a wax pencil; (2) marking with sealing wax; (3) painting with oil colors; and (4) attaching a cerise colored celluloid tag, a method that had serious objections but that yielded the best results. The tag was fastened to the outer lip of the shell with a fine silver wire. All four methods were used at Hampton Roads; at Beaufort, only the celluloid tag.

At Hampton Roads 577 marked drills were set out over bottoms of various types during the year 1927. Because of the depth of the waters those set out over sandy and muddy bottoms could not be recovered; only those planted on oyster beds were found again. For the recovery of the drills dredging was first used; but, since it was impossible to fix the location of the recovered drills and since it did not yield satisfactory returns, this method was dropped. The procedure finally adopted was as follows: A stake was planted at the desired place, around which the marked drills were set. This area was then marked off in concentric circles, 25, 50, 75, 100, 150, and 200 feet from the stake. Each circle had from four to six stations which were tonged at weekly intervals. It was then possible to know the distance and direction of migration. After the first week tonging was done at greater and more scattered distances until approximately one month from the time of planting, when collecting ceased.

TABLE 5.—*Results of migrations experiments at Hampton Roads, 1927*

Approximate distance traveled, in feet	Drills recovered	Time after planting	Approximate distance traveled, in feet	Drills recovered	Time after planting
	Number	*Weeks*		*Number*	*Weeks*
0	2	2–4	75	2	2–4
25	9	2–4	100	6	2–4
50	8	2–4	150–200	1	3

The data shown in Table 5 are few because the possibility of the loss of the identification mark is great and the probability of recovery from depths in which the drill can not be seen is small. The largest loss occurred because of the inability to recover drills from areas not having oysters.

The data obtained at Hampton Roads demanded a further study of the movements of the drill at Beaufort where, owing to the shallow waters, more satisfactory results could be obtained. The oyster beds in this region are either exposed at low water or are just below the low-water mark. The method employed was similar to that used at Norfolk, except for some few minor changes. At low water a stake was driven in the desired locality, and the tagged drills planted. Each day, at low water, the locality was visited and the movements of the drills noted. Since the tags were numbered, it was possible to observe the movements of each drill day by day.

The results obtained corroborate the observations made at Hampton Roads. In every case, even after one month, the tagged drills had not moved over 10 to 15 feet from the original place of planting. This was not due to the presence of unlimited food, because in one case the drills were placed on a hard bottom about 20 feet from an oyster bed and in no case did the drills move to it.

Migration experiments at Hampton Roads and at Beaufort have shown that *Urosalpinx cinerea* does not migrate extensively. This is supported by other evidence. In the study of the distribution of the drill over Hampton Roads it was observed that contiguous oyster beds which had been left undisturbed for two years were infested by oyster drills in different quantities—an observation that was corroborated by several oystermen. The conclusion seems obvious: If any migration does take place such a condition could hardly exist, even though the presence of unlimited food might prevent any pronounced movements. The greater infestation of planted grounds over "natural rock" can not be explained except by the assumption that the drill does not migrate. An analysis of the older literature also supports this conclusion. Although this species inhabits the waters from Maine to Florida the greatest infestation obtains in Chesapeake Bay and in the waters north of it (Rathbun, 1892; Collins, 1890; Hall, 1894; Rowe, 1894; Moore, 1897; Nelson, 1922, 1923; Rich, 1924, 1925), while south of this body of water the pest is insignificant (Ryder, 1883; Dean, 1892; Ruge, 1898; Swift, 1898; Moore, 1898; Grave, 1905). Side by side with this observation is the fact that oyster culture is practiced intensely only in the northern waters; in the southern waters oyster farming is rare. Does not this indicate that oyster planting has something to do with the distribution of the snail?

How is the species distributed? In the author's opinion the agency of distribution is primarily the oysterman. Note his planting operations and the above conculsion is inevitable. The author has known a planter to move 60,000 bushels of oysters from a very badly infested area, having a salinity sufficiently low so that the drills were not doing much damage. Without screening or even forking they were transplanted to another area not so heavily infested but having a more favorable salinity. In one year the new bed was almost a total loss. Though the greatest distributor is the oysterman, there are other agencies. The crabs, especially the hermit crab, spread the animal. The drill attaches itself to the shell, feeds on the encrusting gastropods, crustaceans, etc., and is in this way carried over great distances. The young drills may be distributed by current if they become attached to floating algæ, débris, etc.

TEMPERATURE EFFECTS

Early in the study of the oyster drill it became evident that temperature had a great influence on its activities. During the winter months the animal becomes inactive, remaining attached to the substratum or lying passively on the bottom. A temporary rise in temperature causes slight creeping, but no feeding.

During the winter of 1926–27 about 100 animals were kept in the laboratory tanks and their activities studied in relation to the daily water temperature. Throughout the greater part of December and January they remained totally inactive; in February they showed slight sporadic movements. They crept up the sides of the tank—a reaction which always followed the beginning of activity. Toward the end of February and the early part of March unusually low temperatures occurred, bringing about complete immobility. On March 14, although the temperature rose above 10° C. the salinity was low so that they showed no movement. Inactivity obtained during the latter part of March and early part of April. From the middle of April until early May the animals were inactive because of a combination of low

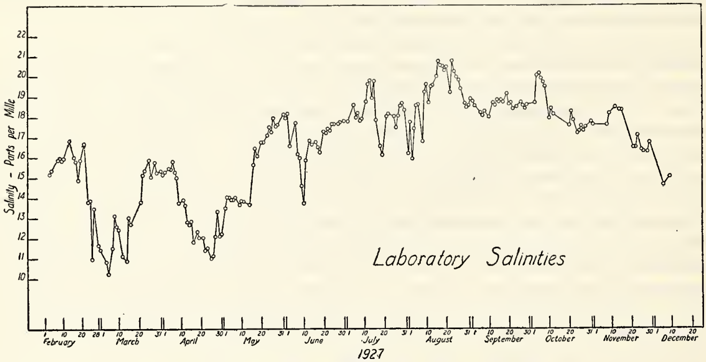

FIGURE 4.—Salinity chart for laboratory sea water at Craney Island

temperature and low salinity; then they became more and more active. These observations were corroborated by those obtained at Beaufort, where temperatures below 10° C. caused immobility.

Temperature affects not only the general activities of the animal but also feeding and spawning. At Hampton Roads during 1927 spawning first occurred in the laboratory on May 19. On May 20 the first egg cases were collected in the field. In Beaufort (1928) the first spawning occurred on March 31. In both cases the water temperature had risen over 20° C. for some time.

Feeding is greatly affected by temperature. At Hampton Roads the drills began to feed during the latter part of March (1927) when the temperature rose above 15° C. On March 23 the temperature fell to 10° C. and feeding immediately stopped, a reaction not due to salinity because on these dates the salinity was over 15.00 parts per mille. (Fig. 4.) Some feeding occurred during the middle of April, and from May 2 (17.5° C.) it continued throughout the summer. During these observations it was also noticed that drilling would be completely halted by a sudden

drop in temperature. The actively drilling animal would stop, leave its victim, and move to some other part of the aquarium. Two sets of data in support of this are available. On August 26 a sudden drop to 20.0° C. occurred (see temperature chart, fig. 5), and the drills that were actively feeding stopped and moved from the oysters. Again, on September 20, 14 drills were observed feeding on oysters. At this time the water temperature in the laboratory was approximately 27° C. On September 24 the water temperature suddenly dropped to about 20° C. and immediately feeding stopped. Again the drills left their oysters and moved away. These same results were obtained in Beaufort. At temperatures below approximately 15° C. feeding ceased, while sudden falls in temperatures during the summer months were equally effective in bringing about a cessation of the drilling activity.

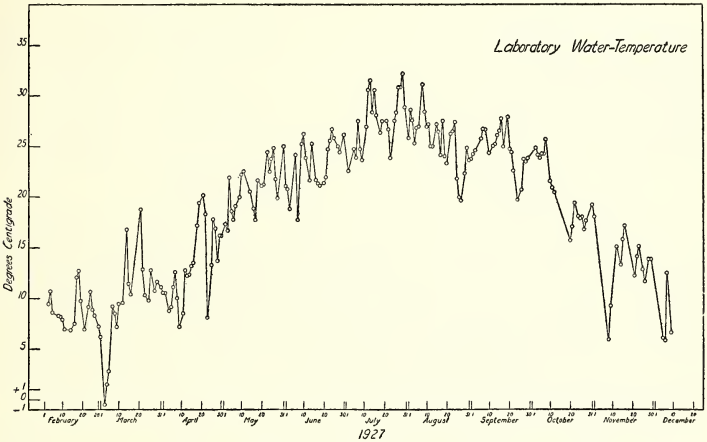

FIGURE 5.—Temperature chart for laboratory sea water at Craney Island. Observations on temperature and salinity were made between 12.30 and 1 p. m.

From the above observations it seems probable that whenever the temperature falls below 10° C. *Urosalpinx cinerea* becomes inactive, and that feeding does not take place at temperatures below 15° C. Even at temperatures above 20° C. sudden drops will interrupt the drilling activity. Spawning takes place when the water temperature has reached 20° C.

FEEDING HABITS

The damage done by *Urosalpinx* has never been accurately determined for oysters beyond the spat age. Rowe (1894) estimated that in southern New England the loss was approximately $1,000,000 yearly, and Nelson (1922, 1923) stated that in Delaware Bay the drill killed as many as 50 per cent of 2-month-old oyster spat. Galtsoff (1925) estimated that in East Haven River (Long Island Sound) 50 per cent of the young oysters had been killed by the drills. In order to get some quantitative data on the actual amount of damage done by this pest to large oysters, surveys

were made over the various oyster beds at Hampton Roads. Oysters were dredged from the desired area, culled, and the dead shells picked out. A record was kept of the total number of live oysters, the total number of dead shells, and the number of "drilled" shells. From these figures the percentage of damage was determined. The surprising fact was the unexpectedly small percentage of deaths from the drill. Table 6 gives a summary of the percentages.

TABLE 6.—*Damage caused by Urosalpinx cinerea over Hampton Roads for June, 1927*

Station	Live oysters	Dead shells	Drilled shells	Dead oysters	Oysters killed by drills in relation to live oysters
	Number	*Number*	*Number*	*Per cent*	*Per cent*
Pig Point	605	104	21	14.7	[1] 3.5
Craney Island Creek	408	75	5	15.5	1.2
Craney Island Flats	103	75	8	42.0	7.8
Mouth of Nansemond River [2]	110	53	1	32.5	.9
East Spit [3]	353	103	28	22.5	[1] 7.8
Broad Rock [4]	72	38	1	34.5	1.4
Western branch of the Elizabeth River [2]	93	32	1	25.5	1.0
Ocean View	709	138	32	16.5	[1] 4.5
Little Bay	332	113	42	25.5	[1] 12.7
Hampton Bar	885	290	180	25.0	[1] 20.0
Tanners Creek	87	31	1	26.5	1.1

[1] Planted areas.
[2] Drills absent.
[3] Stations Nos. 27, E, and F.
[4] Stations Nos. 33 and 34.

The significant figures are in column 6; that is, the percentage of drilled shells referred to the number of live oysters present. These figures show that the percentage of deaths due to the oyster drills is much higher on cultivated oyster grounds than on natural oyster rock, the average for planted bottoms being approximately 10 per cent, that for natural rock approximately 2 per cent. This difference is correlated with the greater number of oyster drills present on cultivated grounds. Why more drills are present on the cultivated areas undoubtedly seems to be explained by the following: (1) The distribution of the drill by man; and (2) the presence of practically unlimited amounts of food.

Although several explanations—Stimpson, 1860 (from Colton, 1908); Ingersoll, 1884 (from Colton, 1908); Schmienz, 1891 (from Flattely and Walton, 1922); Herrick, 1906; and Colton, 1908—as to how the carnivorous gastropods attack their victims have been advanced, the accepted mechanism by which food is obtained is the rasplike radula along with its cartilage and muscles, the whole organ being called the odontophore. The "filing" is done by the radula, a ribbonlike rasp, on which the teeth are fixed. As this wears out it is replaced from the radula sac, growing forward like a nail over its bed as fast as it is worn out in front. The exact method by which the radula is moved has been studied by many investigators. Two theories have been brought forward: (1) The radula moves relatively to its cartilages and its rasping action is due to its own proper motion; (2) the radula remains at rest relatively to its cartilages, and its rasping action is due to the movements of its cartilages. The former was originally advanced by Huxley (1853) a view accepted by Wegmann (1884) and Oswald (1894), later corroborated by Herrick (1906), and at present the accepted one. The latter interpretation is that of Lacaze-Duthiers (1856) and Geddes (1879). Whether or not acid is secreted to aid the drilling is still a moot question, although glands capable of secreting acid have been described in some prosobranchs (Tryon, 1880).

Urosalpinx cinerea feeds on almost all bivalves. The author has observed it feeding on the following animals: Oysters, clams, mussels, *Crepidula*, small crabs, barnacles, and even on its own kind, while other investigators report the drill as perforating scallops (Belding, 1910) and chitons (Arey and Crozier, 1919). Contrary to Colton's (1910) results with Sycotypus and Fulgur, the drill will feed on the meat of oysters, clams, fish, crabs, etc.

The drill's method of attacking an oyster is as follows: After coming upon the oyster the drill selects a valve, the choice of which depends upon many factors, moves over it, chooses a place, and attaches itself, adhering to the substratum by means of the posterior part of the foot. Its proboscis is then thrust out, the odontophore comes into play and the rasplike radula begins to drill. After the shell has been perforated the proboscis is inserted and the animal feeds.

The first question that naturally arises is this: Does the drill limit itself as to the size of the oyster attacked? Field and laboratory observations support the conclusion that it preferably feeds on the smaller and thinner shelled oysters, but that oysters of all sizes are subject to its attack. More than one drill may attack an oyster at the same time—an observation corroborated by Belding (1910) for scallops. But even if one drill succeeds in piercing the oyster shell before the other, the unsuccessful drill continues its rasping, a fact shown by several shells which had as many as four distinct perforations and by direct observations.

As in nearly all other marine mollusks the drill possesses an osphradium—an organ intimately connected with the breathing organs, being generally placed near their base. It consists of a patch of modified epithelium connected by its own nerve with one of the visceral ganglia (Cooke, 1895) and, as was shown by Copeland (1918) for *Alectrion obsoleta* and *Busycon canaliculatum*, is the organ of smell. Through it the drill is undoubtedly attracted to the food.

The selection of the valve to be drilled depends on several factors. The first, purely mechanical, is closely related to the age and size of the oyster. For instance, oysters at the spat stage or less than 1 year old are so attached to the substratum that only the upper or right valve can be attacked. Although this is not so true of larger oysters there are other limitations. Oysters lying flat on the bottom have only one valve exposed which on natural rock is usually the right, and on planted beds may be either. The second important factor in the choice of valve is one which is not at all understood. Observation made by others as well as the author (Pope, 1910, 1911; Nelson, 1923) show that the drill preferably chooses the thinnest shelled animals—a reaction that would undoubtedly bring about the selection of the right shell since that is usually the thinner unless some other response prevented this choice. The third response, which is perhaps the most important of all, is the negative geotropism of the animal. The significance of this is apparent from observations made in the laboratory at Hampton Roads and Beaufort. The essentials were these: Individual oysters of different sizes were placed in tanks so that almost the whole of the two shells were accessible to the drill. The oysters were then arranged so that different parts of the shell would be uppermost. Drills were introduced and in almost every case the hole was made on the shell lying uppermost. These results contradict the observations which showed that the thinner shell is the one chosen. The author believes that this contradiction can be explained on the assumption that the effect of gravity overcomes the response to thin shell.

In the field all these factors play an important part, and depending on the individual bed the results will be different. Two illustrations will suffice. A newly

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planted bed, having only young spat, would show almost all right valves perforated. On the other hand planted beds where oysters average 2 to 3 inches in length and are more or less single the result will give about 50 per cent rights and 50 per cent lefts. This condition exists at Hampton Roads. Out of 123 drilled valves from planted areas 67 per cent were rights—a result that is sufficiently close to be significant, since it would be quite natural to find, even under ideal conditions, more rights because the drills' tendency to attack the thinner shells.

The place of perforation on the shell depends on factors not yet determined. In the examination of this response one interesting fact became apparent. For these observations the area of the shell was divided into small squares and the perforations were correlated with them. Two important results were obtained: (1) Holes occurred on either shell and on every portion of them; and (2) 73 per cent of the perforations were over or near the place of muscle attachment. The explanation for the latter is not evident, although it may be a thigmotactic reaction.

Belding (1910) states that *Urosalpinx cinerea* requires from four to six days to drill through an adult scallop. Experiments (36 in all) made at Hampton Roads show that the average rate in oyster shells drilling is approximately 0.4 millimeter per day. Several factors such as hardness of shell, size of drill, and temperature modify this average.

A study of the reactions of the oyster after perforation gave some insight into the method by which the drill kills it. The first experiments made at Beaufort were as follows: The snail was permitted to drill through the shell of an oyster and then removed and the oyster observed. In every case the oyster eventually died from the perforation, proof that some toxic substance had been injected into it, since oysters which had been perforated with a common machinist's twist-drill continued to live indefinitely. However, there were a few exceptions. If the hole was made by *Urosalpinx* so that only the edge of the mantle was perforated, immediate removal of the drill saved the oyster from death. On the other hand if its perforation was over the adductor muscle, the pericardial cavity, or the visceral mass, the oyster opened almost immediately, while if it occurred at the periphery it might be several days before the adductor muscle relaxed. After the oyster opens, crabs and other scavengers indulge in the feast, hastening the removal of the oyster, and causing the drill to attack new ones. From data collected at Beaufort one drill can kill from 30 to 200 oysters in a season depending on their size.

The drill like some other carnivorous gastropods feeds not only on live oysters, scallops, clams, etc., in the shell, but also on the meat taken from the shell—a fact significant for any method of control that plans to use the meats of these animals and of fishes as baits. Field and laboratory experiments were made in a study of this reaction, but only the latter gave usable results. The difficulty in the field was this: Owing to scavengers and putrefaction the bait did not last long enough to allow the drills to react to it, and although various types of cages were used to eliminate the scavengers it was impossible to keep the bait for longer than 12 hours (during the summer months, which is the time most favorable for trapping, because the drills are then most active), which was of insufficient duration.

In the laboratory, experiments were devised to find out what meats the drill prefers and the maximum distance at which these are effective in attracting the snail. Completely satisfying results could not be obtained especially to the latter question, because the baits putrefied before the drill could get to them. The experiments were conducted in the following way: Meats of freshly killed oysters, clams, scallops, pin-

fish, spots, croakers, oyster drills, and *Crepidula* were placed at one end of a tank of areated sea water. The water was not permitted to run in these tanks because of the effect of currents on the movements of the drills (Federighi, 1929). At varying distances tagged drills were introduced and their movements noted. Although no results were obtained as regards the greatest distance at which the drills react to the foods some data were collected on the relative efficiency of the various meats. It was found that oyster meat is preferred to any other, and mollusks are preferred to fishes. In one of the experiments there was introduced besides the various meats some oyster spat. The result was that the drills attacked these shelled oysters in preference to the more easily available meats. It is true that not all the drills went to the shelled oyster spat, but a good number did and this in spite of the fact that they had to pass by some freshly killed oyster meat to get to them.

BREEDING HABITS

In *Urosalpinx cinerea* as in other prosobranchs the sexes are separate, the males being distinguished by a large curved penis which lies at the right side of the head behind the eyes. The two sexes can also be separated by macroscopic examination of the gonads, the male glands being whitish in appearance; that of the female yellow to orange in color. The eggs are laid in small, yellow membranous, vaselike capsules attached to the substratum by a solid expanded foot. The egg case is flattened vertically with edges marked by keellike ridges and has, at the top, a small cap through which the fully grown larvæ escape. Within the capsule is a soft jellylike fluid in which the eggs are laid and which serves not only to protect them from mechanical injury but also as a source of food. At Hampton Roads during 1927 the first egg cases were collected in the field on May 20 and in the laboratory on May 19, while at Beaufort the first egg cases were gathered (during 1928) on March 21, and in the laboratory on March 30. Spawning continued throughout the summer, and during the fall it gradually decreased in intensity until at Hampton Roads spawning practically had ceased by the 1st of October.

The details of spawning, development, and hatching were studied in the laboratory. The work included observations on the following subjects: (1) Copulation; (2) behavior of the female during spawning; (3) the number of times a single female spawns during one season; (4) duration of oviposition; (5) the rate of oviposition; (6) the number of egg cases laid per female; (7) the number of eggs per egg case; (8) duration of the incubation period; and (9) the percentage of drills hatched.

Although copulation undoubtedly occurs in *Urosalpinx cinerea*, copulating drills were never collected in the field nor was copulation ever observed in the laboratory—a fact probably explainable by assuming that copulation occurs only at night. For this reason it is not known whether the drill copulates more than once a season or whether the sperm are carried over from year to year.

Because of the snail's negative geotropism the female creeps up to the higher levels to spawn. Without this response the eggs would be laid in the lower strata and be suffocated and buried in the mud. In almost all cases if oysters were present in the tank the female would climb on them to deposit the capsules in preference to the sides of the tank. While spawning the female does not feed but remains attached to the substratum and unless disturbed continues until spawning is completed. Observations in the laboratory show that each snail spawns only once during the summer, although in some cases, when the animal was disturbed while spawning, it would cease, move away, and for several days show no spawning activities. After a few

days it would resume its egg laying. In many cases the snail would return to its "original" spawning grounds. Such a response if the animal's previous history were unknown might give the impression that spawning occurred more than once during a single season.

Oviposition lasts for various lengths of time, depending on whether the animal is disturbed. Sudden drops in temperature or lifting from the substratum bring about cessation of the spawning reaction, so that it is difficult to determine accurately the duration of spawning. During 1927, at Hampton Roads, 6 animals were observed in which spawning was accomplished without any apparent interruption. In these the average time was approximately 7 days, during which time an average of 28.8 cases were laid per female. As is shown later these figures agree very closely with those obtained from an analysis of the rate of oviposition and the number of egg cases laid per female. The rate of oviposition was determined by observing 19 females that spawned 127 egg cases in 32 days, an average per female per 24 hours of 3.9 egg cases. This figure is very close to that obtained from the data on the duration of spawning in which a female spawned 28.8 egg cases in 7 days or 4.1 egg cases per female per 24 hours.

In order to determine the number of egg cases one female lays in a season, several animals were isolated and the number of egg cases laid by each one noted. These females were kept isolated throughout the whole summer in order to be sure that no further spawning took place. The data obtained from these observations support the figures previously given for the duration of oviposition. The average rate of oviposition is 3.9 egg cases per day, and the average number of egg cases laid per female is 28; thus each female, if undisturbed, would require approximately 7 days to complete her spawning.

Examination of 727 capsules collected during the summer of 1927 at Hampton Roads gave an average of 8.8 eggs per egg case. The smallest number of eggs per capsule was 3; the largest 22.

In order to determine the incubation period of the drill, freshly laid egg capsules were isolated and the time when hatching occurred noted. These experiments were necessarily performed in the laboratory. Eleven different batches of egg cases were thus isolated during May, June, July, and August. The following table (7) summarizes the results. The average incubation period obtained from these figures is approximately 40 days.

TABLE 7.—*Summary of the results on the incubation period of Urosalpinx cinerea obtained in the laboratory at Hampton Roads during summer, 1927*

Time egg case was laid	Incubation period	Minimum and maximum temperatures during incubation period [1]	Time egg case was laid	Incubation period	Minimum and maximum temperatures during incubation period [1]
	Days	° *C.*		*Days*	° *C.*
May 20	36	18.0–26.0	June 23	37	22.0–32.0
Do	38	18.0–26.0	July 9	44	24.0–32.0
May 23	38	18.0–26.0	July 12	42	24.0–32.0
June 20	39	21.0–32.0	July 15	40	24.0–32.0
June 22	43	22.0–32.0	Aug. 11	44	20.0–30.0
Do	41	22.0–32.0			

[1] See Figure 5 for daily temperatures during these periods.

Since the period of oviposition varies greatly the period of hatching is also varied, and one finds in a single group of egg cases embryos in different stages of development. This undoubtedly explains the variations in the incubation period (Table 7), since it is impossible to tell the exact age of the embryos within the capsule at the time they were isolated.

Brooks (1879) reported that some of the embryos in the capsules of *Urosalpinx cinerea* broke up, the separate cells swam about, and were drawn within the digestive cavities of other embryos. This suggested that some observations should be made on the number of larvæ hatching from the egg cases. Although the data given below are not many, they serve to indicate the magnitude of the percentage of drills hatching. Twenty-eight capsules gave rise to 144 larvæ, an average of 5.1 larvæ per capsule. Since the average number of eggs per egg case was determined as 8.8, the average percentage of eggs hatching into larvæ is about 58 per cent.

Besides these observations it seemed desirable to study the effect of salinity on the spawning of the animal, since in the transplanting of oysters, *Urosalpinx cinerea* is sometimes subjected to waters of very different salinities. The study was undertaken to show: (1) The effect of salinity upon the number of egg cases laid, and (2) the effect of salinity on the number of eggs per egg case. Between May 5 and May 26, 1927, at Hampton Roads 13 crates made of fine mesh wire and each containing 50 drills and about 1 bushel of oysters were distributed in various places of salinities varying from 4 to 20 parts per mille. Two crates were planted at each station; one at the surface, the other at the bottom. These were visited at definite intervals, egg cases collected, and the condition of spawning noted. The work was only partially successful because by July 1 the crates had all disappeared. The results shown in Table 8 are significant in that they show that the oyster drill reproduces wherever it survives. Salinity does have some effect on the number of eggs per egg case as is evident from the table. A salinity of 17 parts per mille seems the optimum salinity for the number of eggs per egg case at Hampton Roads.

TABLE 8.—*Effect of salinity on the spawning of Urosalpinx cinerea at Hampton Roads, 1927*

Average salinity	Number of egg cases counted	Average number of eggs per egg case	Approximate date of spawning	Average salinity	Number of egg cases counted	Average number of eggs per egg case	Approximate date of spawning
4.00	(1)	(1)	(1)	15.00	97	8.4	May 20
7.00	(1)	(1)	(1)	17.00	109	9.3	Do.
12.00	44	8.9	May 15	20.00	43	8.9	Do.

1 Drills all killed.

TROPISMS

The study of the natural history of any animal must be supplemented by laboratory experiments, where conditions can be controlled and the behavior of the organism more easily analyzed and interpreted. Although it is true that conditons in the laboratory never exactly simulate the field or the natural environment, laboratory results are important in permitting one to predict what the animal will do when subjected to certain isolated stimuli. After all, the behavior in the field is only the result of several reactions working simultaneously. In the laboratory these reactions are isolated and studied individually. If inconsistencies are found between the results obtained in the laboratory and the responses in the field, one must not condemn laboratory work as the fault usually lies in insufficient data. In order to arrive at some means of controlling the oyster drill it is necessary to know something of its responses

to the stimuli to which it is normally subjected. These observations can not be made sucessfully in the field.

Geotropism is characteristic of many different animals. Although the theories devised to explain this response are many and varied (see Cole, 1925–26; Crozier, 1928 for complete bibliographies on the subject), there are only two hypotheses that seem to be acceptable: (1) A theory which proposes that the gravity responses depend on the otolith-apparatus (Lyon, 1905; Baunacke, 1913; Kanda, 1916, 1916b), and (2) a theory which suggests that geotropic orientation may depend on the stimulation of proprioreceptors in the symmetrical parietal musculature (Cole, 1917, 1925–26; Arey and Crozier, 1919; Crozier and Federighi, 1925; Crozier, 1928). During the spring, summer, and fall—that is, when the temperature rises above 10° C. and the animals creep about actively—*Urosalpinx cinerea* exhibits a very pronounced negative geotropism. Such a reaction is important in that it is successful in keeping the egg capsules from being laid on the bottom where they would be covered with silt and the embryos killed.

That this is a geotropic response is shown by the following observations. It persists in the dark room and when the eyes are removed; and is not dependent on oxygen content because experiments have shown that animals in areated sea water, where presumably the water is saturated as to oxygen, will give the geotropic response. If an animal is allowed to adhere to a glass plate, the plate raised vertically, and then turned as a wheel on its hub, thus changing the orientation of the animal, the snail will always turn so that the siphon points up and the shell apex down. The direction of body turning—that is, either clockwise or counterclockwise—depends on the side on which the apex is placed since in every case the apex moves down.

The explanation for the absence of any negative geotropism during the winter months is not altogether clear. Two hypotheses may be suggested: (1) The low temperature may bring about a reversal in the response as in lower animals (Massart, 1891; Sosnowski, 1899), or else (2) negative geotropism is dependent on the activity of the animal, an explanation that is probably the true one. This loss of geotropism is significant for any method of control which plans on trapping the drill by means of a dredge (Moore, 1897) and also for the pillar method which is described later.

The rheotropic response is found among many animals (Schulze, 1870; Verworm, 1899; Wheeler, 1899; Parker, 1903, 1904; Tullberg, 1903; Lyon, 1904; Dimon, 1905; Jordan, 1917, 1917a; Arey and Crozier, 1919, 1921), and it seems to be dependent on different sense organs in different animals. Bonnier (1896) believed that the rheotropic reaction of fishes was dependent on the lateral line organ, while Parker (1903, 1904) showed that in *Fundulus* the receptor for this response is not the lateral line organ but the skin. Tullberg (1903) believed the ear to be the organ directly concerned with the reactions of fishes to currents. According to Lyon (1904) "the primary cause of orientation in streams of some uniformity of motion is an optical reflex, a tendency on the part of the animals to follow the field of vision." Jordan (1917, 1917a) found for *Epinephelus striatus* Bloch that the end organs concerned in rheotropism are located in the integument and that these organs are the organs of touch, which also serve as the essential organs of current stimulation.

If *Urosalpinx cinerea* is placed in a water current it will orient itself so as to bring the siphon pointing upstream, the shell apex downstream, and move against the current. The response is definite and immediate. The removal of eyes and tentacles does not interfere with the normal behavior of the drill, and experiments carried on in the dark room also gave similar results. Here evidently is a rheotropic

animal that is admirably suited for quantitative study. The following is a brief account of these studies which has already been published in detail elsewhere (Federighi, 1929). Two phases of the response were studied: (1) The relationship between the rate of current and the rate of creeping, and (2) the effect of the current rate on the rate of turning.

In these experiments the animals were placed in a trough suspended in a current of water of the turbulent flow type. For the experiments on the rate of creeping the time necessary for the animal to move one-half inch was taken as a measure of the rate of creeping. The rate of turning was determined by tracing the path of orientation and recording the time necessary for its orientation, then measuring the distance thus traveled with a map measure, and finally recording the number of degrees through which the animal had passed. Knowing these, the degrees turned per centimeter of path at each current rate used was obtained. Surface current velocities of from 1.25 centimeters to 7.6 centimeters per second were used. These were determined by recording the time necessary for uniform bits of cork to travel 5 inches. Between 15 and 20 readings were taken for each velocity and these averaged. At each velocity at least 10 readings for each animal were taken on the rate of creeping or turning, and the average of these taken as the figure for that velocity. In all, 14 animals were used in the study of the effect of the rate of current on the rate of creeping and 11 for the observations on the relation between current rate and rate of turning.

A summary of these data shows that: (1) Creeping and turning are dependent on different mechanisms; (2) the rate of turning—that is, the degrees turned per centimeter of path—is a function of the current velocity, and that when plotted respectively as effect and intensity the curve obtained follows the usual effect versus intensity curve; (3) although the rate of creeping is independent of the current rate, the amount of resistance overcome—or the work done—is also a function of the current velocity; (4) creeping depends either on the ciliated pedal surface or on muscular activity, and in either case these are not affected by the flow of fluid past the animal; (5) turning depends, apparently, on the parietal musculature of the animal. The unequal tension on the two symmetrical parietal muscles, produced by the pull of the shell, which in a stream tends to straighten out so that the shell presents the least resistance to the flow of water with the foot mass as a pivot, is the stimulus which brings about orientation. After the animal has become oriented, there is no effect produced on the rate of creeping; the current acts only to keep the animal oriented.

Experiments on the behavior of the drill under the influence of light were without results, indicating that under the conditions studied, the drill is not phototropic.

Aside from any theoretical significance the tropistic behavior of the drill has a practical application. The response to currents has doubtlessly a great influence on the direction of its movements and its negative geotropism is important in the consideration of any means of control and in the success of its spawning.

CONTROL MEASURES

The preceding study of the life history, habits, and behavior was undertaken in order to devise some means to control *Urosalpinx cinerea* or at least to prevent any further invasion. At this stage the investigator feels very keenly how difficult this is. Any problem that involves the control of the number of individuals in a species already adapted to its mode of life, already having reached an equilibrium

with its surrounding environment, is confronted with tremendous difficulties. It is wise therefore at this time to take up: (1) The factors which are aiding the increase of the pest, (2) the factors which might presumably aid man in his combat with the animal, and then (3) the means by which man may control or at least prevent further infestation.

The soft body of *Urosalpinx cinerea* is covered by a hard calcareous shell well fitted to protect it from the attacks of other animals. Under adverse conditions the body retreats into the shell and the opening is effectively closed by a chitinous operculum, so that the animal can withstand unfavorable salinities and dessication for long periods of time. Besides this structural protection, it is fortunate in having no known enemies except itself.

The spawning habits of the drill insure protection to the embryo, the best supply of food for the young, and a means of distribution. The eggs, inclosed in leathery capsules, protected from the elements, and supplied with food, are laid near or preferably on a bivalve. There being no free living larval stage, the embryos remain within the egg case until completely developed and on hatching begin to feed immediately. The attachment of the capsules to oysters is of great importance. Oyster transplanting usually takes place during the summer months when the drills are spawning, so that even though the oystermen remove the adult drills when transplanting from an infested area, the egg cases still remain. A new area is infested and in a year or two the new drills cause great damage.

The size and the adhesive property of the snail are significant in successful drill control. Approximately three-fourths of an inch in length, its dull grayish-brown color blending almost perfectly with the background, the oyster drill is almost completely hidden. It adheres tenaciously to the substratum, making it difficult to remove by the ordinary methods. If this is so, what about the newly hatched drills that average from 0.8 millimeter to 1 millimeter (about $\frac{1}{25}$ inch) in length?

Perhaps the most important factor that prevents successful oyster drill control is the practice of transplanting oysters regardless of the presence of drills. Thus the oyster planter, by his careless habits, acts as a distributor of this pest, infesting new areas daily.

Against these factors that aid the increase, the distribution, and the destructiveness of the oyster drill, we can place the following: (1) The lack of any pronounced migratory habits and its inability to cross or inhabit muddy areas. (2) Temperature, since during the winter months in waters whose temperature falls below 15° C. no feeding takes place; when the temperature rises above 10° C. the animals are negatively geotropic; they move to the upper surfaces of the oysters and are more easily gathered. (3) Females are generally larger than the males; therefore in any culling process the probability is that the animals removed will be largely females; the significance of this is obvious. (4) The salinity data given above shows that the drill can not withstand salinities as low as those which the oyster can endure. Oyster spats that occur up the river in waters of low salinity are protected from the attack of this pest, and only when man moves the oyster seed down into more saline waters, or an unusually dry season occurs, does the drill become destructive.

For the control and removal of *Urosalpinx cincerea* certain methods are given in the following paragraphs. These have already been published in a preliminary report. (Federighi, 1930.)

Two problems confront the oysterman in combating this species: (1) The removal of drills from areas already infested, and (2) the prevention of the infestation of new areas.

METHODS FOR REMOVAL FROM INFESTED AREAS

(*a*) *The trap dredge.*—As is seen from the illustration (fig. 6) the dredge consists of a wire cage open in front and fitted with an inclined screen. The dredge is dragged over the infested oyster bed; the oysters are picked up by the blade at the edge of the dredge, moved up over the inclined plane, and the drills automatically screened, falling into the cage below while the oysters pass over and fall back onto the oyster bed. In this way the dredge can be dragged over great areas, without involving the removal of the oysters from the bottom. The dredge is quite satisfactory, provided the oyster population is not too dense.

The most effective time for dredging is the early spring when the animals have become active and are on the upper layers of the oysters, but before spawning begins. If it is done at this time the females are removed before they have spawned and so the young are eliminated. Furthermore, dredging during this season is more effective than in the winter months, since, when active, the animals creep to the top and are more easily accessible. The proper time for dredging at Hampton Roads is the latter part of March; for the Beaufort region the best time is the early part of March.

(*b*) *The use of small concrete pillars.*—Small concrete pillars, easily handled by one man, may be set out over the infested areas. These pillars, providing surfaces higher than the surrounding area of the oyster beds, act as traps because the animals congregate upon them, owing to their tendency to creep upward. After three or four days they are taken up, the drills removed, and the pillars set out again in new places. If the area is below low-water mark, lines and buoys can be attached to the concrete blocks, thus facilitating removal and replacement. Pillars of the size shown in the illustration have collected as many as 500 drills in three days from experimental tanks which were heavily infested. Although no field observations have been made with concrete blocks, sand-filled buckets placed on infested beds have collected a great many drills.

(*c*) *Dredging with an oyster dredge fitted with a small-mesh bag.*—This method is practicable only if the infested oyster bed is being dredged for oysters which are to be marketed and if the oysters are all to be taken up. The procedure is as follows: After most of the oysters have been taken up, the bed is worked with a dredge having a very small-mesh bag. In this way the drills, shells, and other débris are taken up and can later be disposed of by burning or drying in the sun. It is important that the infested bed be gone over carefully with such a dredge. After this has been done, uninfested oysters can be planted in such a locality without fear of loss from drills.

METHODS FOR PREVENTING DISTRIBUTION

The solution of the problem of the further distribution of the pest is not as difficult as that which involves the cleaning of infested areas. Because the drill is almost nonmigratory the infestation of new areas is easily controlled. The oyster planter must be careful not to plant infested oysters in noninfested areas. Before doing this it is necessary for him to remove as many of the drills as he can by use of methods described below.

(*a*) *The use of forks.*—This method is inexpensive and simple. After the infested oysters have been put aboard the oyster boat, they are thrown overboard onto the new

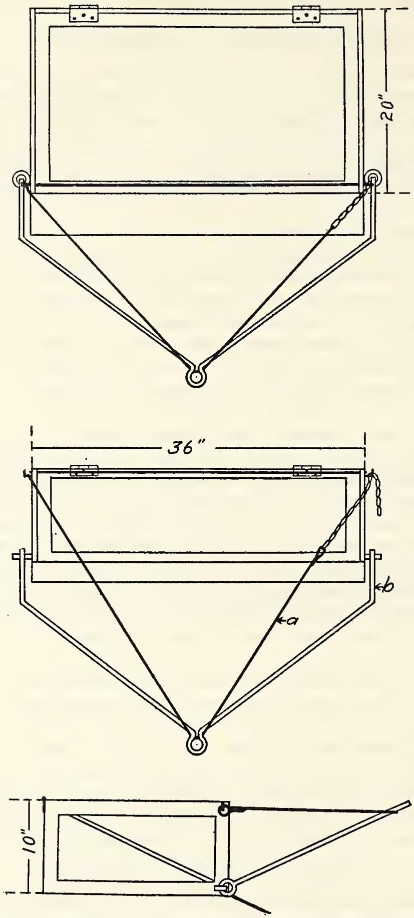

FIGURE 6.—Figure of modified drill-trap dredge. Approximate dimensions are: Length, 36 inches; width, 20 inches; height, 10 inches. Sides and back to be covered with fine hardware cloth so as to prevent the escape of the trapped drills. The lid to be covered with wire screen small enough to prevent oysters from falling into trap but large enough to allow the drills to pass through easily

bed not by shoveling but by using forks such as are employed by farmers. A forkful of oysters is taken up, and before throwing them overboard they are shaken on deck a couple of times by dropping them and taking them up again. In this way a good many of the drills are shaken off, fall on the deck, and can later be destroyed. This method involves no expensive apparatus or excessive time. The only expense is the slightly longer time required to throw the oysters overboard.

(*b*) *Screening.*—A little more expensive than forking, screening is a little more efficient. The method is essentially similar to that used to screen sand from gravel. The infested oysters which have been dredged and placed on deck are allowed to remain in the air for several hours. This loosens the drills from the oysters so that they can be shaken off more easily. After this exposure to the air the infested oysters are thrown against a screen, the mesh of which is sufficiently large to permit the drills to fall through but small enough so that the oysters will not. One-inch, double-weight-mesh chicken wire answers the purpose very well. There are several advantages to screening the oysters aboard, providing the boat is sufficiently large. It eliminates the expense involved in handling the oysters; and the screened oysters can be thrown overboard, using forks, immediately after they are screened, thus doing away with one more handling. The drills that fall through the screen can be destroyed by burning or by drying in the sun.

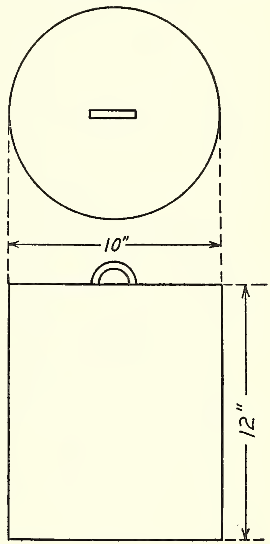

FIGURE 7.—Small, concrete pillar for the trapping of oyster drills. A hook embedded at the top facilitates handling when the pillars are to be planted below the low-water mark. To the hook can be attached a line and buoy, making the trap easy to find.

(*c*) *Floating.*—The effectiveness of this method depends on the fact that drills are killed in brackish water which, however, is not fresh enough to kill the oysters. This method is very efficient, and its efficacy warrants its use in heavily infested beds, even though the oysters are not to be transplanted. The procedure is this: It is first necessary to find the exact dilution of sea water which is fatal to the drills of a given locality. This is important because it has been found that drills taken from various regions can sustain different dilutions, depending on the salinity of the water in which they were grown. After this has been determined, the infested oysters are placed in large cars and kept for about 10 days in waters of the lethal dilution. In this way the snails are killed without harming the oysters. The method has the further advantage in that it kills not only the adult animals but also the small newly hatched individuals, which in other control measures usually escape. After the drills have been destroyed, the now uninfested oysters can be planted on clean beds. For Hampton Roads the lethal dilution, or death-point salinity, is approximately 12 parts per 1,000; for Beaufort, it is slightly higher, about 14 parts per 1,000. It is important not to crowd the oysters when floating them, otherwise a great many will die.

SUMMARY

The preceding studies may be summarized as follows:

1. The common oyster drill (*Urosalpinx cinerea*) is a carnivorous gastropod, about three-quarters of an inch in length, possessing a hard calcareous shell varying in color from light brown to white. The animal is small, the foot scarcely covering the aperture.

2. The snail inhabits the marine and brackish waters of the Atlantic coast from Maine to Florida, occurring also in San Francisco Bay, Bermuda, and England. At Hampton Roads it is found only below the low-water mark while in Connecticut and North Carolina it is present on beds exposed at low water. Muddy bottoms, clear sands, and depths greater than 25 feet are unfavorable for its growth and multiplication. More animals occur on planted bottoms than on natural rock.

3. Laboratory experiments at Hampton Roads and at Beaufort on the salinity death point of the drill, collected from areas having different average salinities, show that the salinity at which the animal dies (or the salinity limiting the distribution of the animal) depends upon the salinity of the environment from which the animal has been collected. In other words, the snail is capable of a large degree of adaptation to low salinities. It is important to know just how far this adaptation can be carried in order to know whether or not the setting areas will ever be threatened.

4. The exact mechanism of creeping in the oyster drill is still unknown. Either it creeps by muscular activity (arhythmic pedal waves) or through the cilia of the pedal surface. Tagging experiments, distribution observations, and an analysis of the older literature show that the animal does not migrate but that its distribution is dependent on the planting activities of man and on the migrations of other animals such as crabs to which they sometimes attach themselves.

5. Observations on the relation between temperature and the activities of the animal show that: (*a*) The animal becomes inactive at temperatures below 10° C.; (*b*) feeding does not occur until the surrounding temperature reaches 15° C.; and (*c*) spawning takes place only when the temperature is above 20° C.

6. Hampton Roads has not suffered as greatly from this predatory gastropod as has been reported. The percentage of deaths from drills in relation to the number of live oysters present rarely exceeds 3 per cent excepting on planted beds where it is sometimes as high as 20. Areas, where setting occurs and where beds of young oysters are found, necessarily suffer greater damage because the spat are more easily pierced and yield only a small amount of food. The mechanism of drilling is the radula, a rasplike organ which moves over its cartilages much as a belt over a pulley. *Urosalpinx* confines itself not only to drilling a great many living mollusks and crustaceans, but will also feed on the meats of these animals. Although out of a batch of oysters of all sizes the smallest and thinnest shelled are killed first, it has been shown that all oysters, no matter how large, are attacked by the drill. The choice of the valve drilled depends on many factors which are enumerated and the significance of each given in the text. The place of perforation depends on factors not yet known. In three-quarters of the valves examined, the hole occurred at or near the place of muscle attachment although any portion of the shell may be drilled. In oysters, drilling progresses at approximately 0.4 millimeter per 24 hours. The behavior of the oyster, after being drilled, depends largely upon the position of the hole. It is believed that the drill injects some fatal toxic substance into the body of the oyster.

7. Although there is no sexual shell characteristic in *Urosalpinx cinerea*, the sexes are separate. The eggs are laid in leathery, vaselike capsules attached to the

substratum by means of a solid expanded foot. Each female spawns only once a season which at Hampton Roads is from May 15 to September 30. About 28 egg cases are laid per female, and each capsule averages 9 eggs. After approximately 6 weeks, there being no free-living larval stage, the young, about 1 millimeter in length, escape from the capsules through a cap at the top of the egg case and begin to feed immediately. Approximately 60 per cent of the eggs hatch into larvæ. Studies on the relation between salinity and spawning showed that the animal will spawn at any salinity at which it will live.

8. Studies on the tropistic behavior of the snail were limited to a study of its geotropism, rheotropism, and phototropism. (*a*) During the months when the drill is active, it shows a very definite and marked negative geotropism which is important in its spawning reactions. Because of this, the animal climbs up to the higher levels to lay its eggs, and thus they are not covered with mud and suffocated. Experiments have shown that this is a true geotropic reaction and not one in response to oxygen content or light. (*b*) If the snail is placed in a current of water it will orient itself so that its siphon is pointing upstream. It will then creep in that direction. Studies on the relation between current velocity, and the rate of creeping showed that creeping is independent of current velocity. The rate of turning (orientation) is a function of the current velocity. Light does not affect the movements of the drill.

9. The oyster drill can be greatly reduced in numbers provided the oyster planter is willing to make a little effort. Because the snail is practically nonmigratory its further distribution can be checked. If an area, at present infested is cleaned of this pest, there is no reason why it should not stay so, provided the planter is careful not to reinfest it with oysters from an infested area. The oyster planter must be careful of two things: (*a*) He must not move oysters from an infested area to a noninfested area without first attempting to clean the infested oysters. This can be done by any of the following methods: The use of forks, screening, and floating. (*b*) He must avoid planting uninfested oysters on infested bottoms. The infested bottoms can be cleaned by the use of a trap dredge, the use of small concrete pillars, and the use of an oyster dredge fitted with a bag of small mesh. If these recommendations are adhered to the oyster drill pest will gradually decrease in importance.

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JUVENILE AND SEX CHARACTERS OF *EVORTHODUS LYRICUS* (FAM. GOBIIDÆ)[1]

By Isaac Ginsburg, *Assistant Aquatic Biologist, United States Bureau of Fisheries*

INTRODUCTION

Two species of gobies, which have been recorded from the Gulf coast of the United States and Mexico and which have been placed in separate genera based on characters which were universally accepted by taxonomists as generic, have been found to represent the two sexes of one and the same species. These two species are *Gobius lyricus* Girard and *Evorthodus breviceps* Gill. The latter species has been described from Trinidad, but it also has been reported from the Gulf coast of Mexico by Jordan and Richardson. The author has found it to be quite common in Louisiana. The young, described from Chesapeake Bay, have been placed in still another genus. The female has been named three times, the male independently twice, and the young once.

Full-grown specimens of these two supposedly distinct species are readily separable by the character of the teeth. In *E. breviceps* the teeth are minute, as seen superficially, their distal margins are notched, and they are placed side by side in a single row. In *G. lyricus* the teeth are considerably larger, their margins entire, they are rather widely spaced, and the lower jaw has a row of larger teeth, usually four to six in number, behind the outer row. A band of small teeth has also been described in the lower jaw of the latter species, but this is evidently due to an error of observation. What appears like a band of villiform teeth is really a band of papillæ as has been determined by dissecting out the papilliferous mucous membrane, drying and examining it under a microscope.

During the summer of 1930 while collecting on the coast of Louisiana, the author found these fishes fairly common on Grand Isle and adjacent small islands in Barantaria Bay. Their favorite haunts are small marshy ponds with muddy bottoms, which communicate with the inner larger bodies of water at high tide but are isolated at low tide when they have a depth of about 2 to 4 feet. The remarkable similarity in the appearance of the two nominal species was striking and considering also their constant association, the idea of their being the two sexes of one species came to mind; but in view of the difference in the character of the teeth and the opinions of previous workers, this notion at first was dismissed as untenable. However, a minute examination of the teeth has shown that in many specimens of intermediate size both kinds of teeth occur. This led to an extensive study of the teeth of many individuals, the sex of which was determined by dissection. This study has shown that *Gobius lyricus* is the male and *Evorthodus breviceps* the female of the same species.

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[1] Approved for publication, Jan. 23, 1931.

The structure of the teeth, which has been relied on to separate the genera differs radically with the sex and also with age as follows. In the young below 25 millimeters in total length, the teeth are quite small, flattened, proximate, in a single row and their distal edges are apparently entire, at least so far as examination with a binocular microscope discloses. Between 25 and 30 millimeters in length the teeth in both sexes change to those having their distal margins distinctly notched. In the female the single row of notched, small, compressed and proximate teeth remains throughout life. In the male, however, a radical change in the character of the teeth takes place with age. When the young male reaches a length of between 35 and 40 millimeters, two to four enlarged teeth begin to appear in the lower jaw behind the outer row of small teeth. In the larger males this second row of enlarged teeth number as

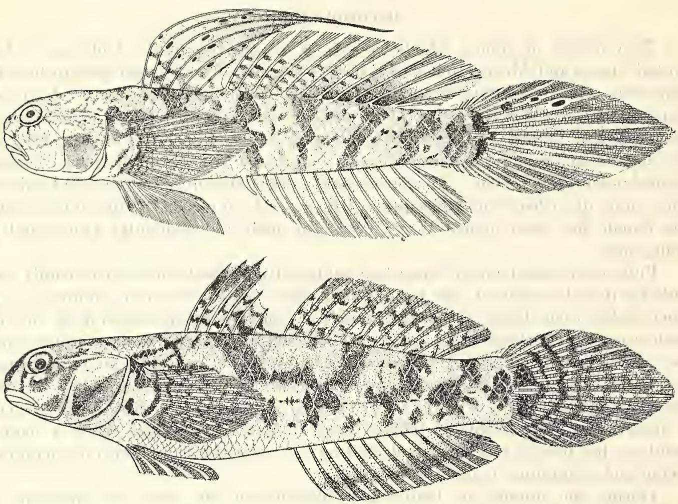

FIGURE 1.—*Evorthodus lyricus.* Upper, mature male; lower, mature female. Drawn by Miss Louella E. Cable from specimens taken on the coasts of Louisiana and Texas

high as 8, the usual number being 4 or 6. The outer row of teeth remains as in the female in specimen up to about 40 millimeters. After the fish exceeds that length they begin to change once more. The teeth become longer and more widely spaced, and their edges are entire. The larger, entire teeth first appear at the symphysis of the upper jaw and gradually spread sideways. The change is gradual; and some small bifid teeth, intercalated with the larger teeth, may be present in males as large as 72 millimeters, although they usually disappear at about 60 millimeters. In the lower jaw the change takes place later, between 55 and 60 millimeters in length. After 72 millimeters in length the teeth become pointed, fanglike as compared with that of the female, and rather widely spaced, so that when full-grown specimens are compared their widely different characters are quite striking.

Not only have the males and females been placed in separate genera, but the young have been described in still another genus. As has been stated above, the very

young have teeth similar to that of the female but with entire edges. The lower jaw is also rather thin and somewhat pointed; and this together with the single row of minute movable teeth, suggests the mouth of a mullet. They have consequently been described under a separate genus, *Mugilostoma*.

The conclusions stated above are based on a study of 86 males, 22 to 79 millimeters in length, and 82 females, 30 to 68 millimeters, from the coasts of Louisiana and Texas. A total of 52 have been dissected, and the sex of the gonads determined by teasing out a small portion and examining with a compound microscope, except in the case of females with well-developed eggs in their ovaries. It might be added that if one wishes to correlate the difference in the teeth with the sex and

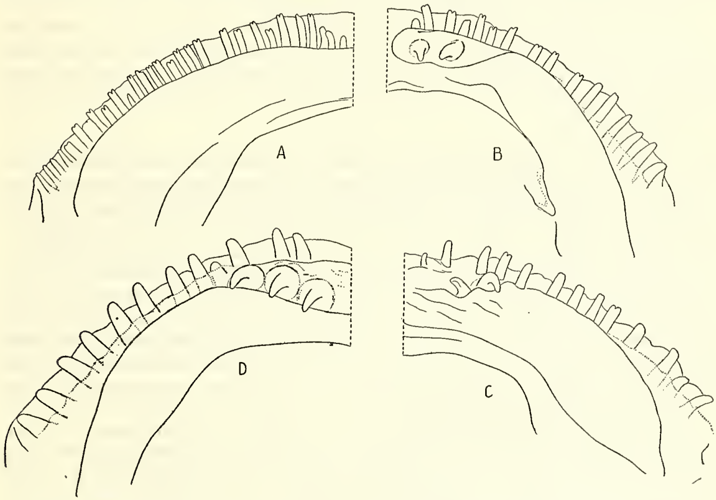

FIGURE 2.—Camera lucida drawing by Miss Louella E. Cable of the inner surface of one side of the lower jaw. A, female 65.5 mm. B, male 60 mm. C, male 67 mm. D, male 69 mm. Note the striking difference, heretofore considered of generic importance, between A and D, and the gradual change in the male from B to D. In the upper jaw of the grown male the teeth are considerably larger than in the lower, and the change in the young male takes place much sooner. The smallest male figured already has the majority of the teeth in the upper jaw typically that of the grown male, and the contrast between the large raptorial teeth and the smaller bifid teeth quite striking

the changes in the character of the teeth in the male, it is not necessary to examine the gonads microscopically since, like in many other gobies, the anal papilla forms an external character usable to separate the sexes readily. In the male the anal papilla is rather long, slender, and pointed, while in the female it forms a fleshy, bulbous tubercle and has a very deep fossa between it and the anal fin. This character readily separates the two sexes, except those of 27 millimeters or less when the difference is usually not marked.

The collections from the Gulf coast have been used to work out the changes due to age and to sex. In order to fix definitely the status of the species and its distribution and to include in the synonymy the various names under which it was previously described from time to time, the following material has been studied.

U.S.N.M. 646. Rio Brazos, Tex. G. Wurdemann. Cotypes of *Gobius lyricus*. The bottle contains seven specimens. The largest one, 77 millimeters total length, is a male of the present species. The other 6 specimens are examples of *Gobionellus boleosoma* (Jordan and Gilbert), 2 females 34 and 41, and 4 males 47 to 52 millimeters total length. Girard, therefore, confused the two species, probably assuming the smaller species to be the young of the larger one; and it becomes necessary to decide to which one of the two species his name is to be applied. Girard's figure is inaccurate and is not characteristic of either species, although it is reasonable to assume that he figured the largest specimen; while the inadequate description may apply to both species. In order to fix definitely the status of the name *lyricus*, the largest specimen is hereby designated as the lectotype.

U.S.N.M. 34456. Trinidad, West Indies. T. N. Gill. A single specimen, type of *Evorthodus breviceps*, in bad condition. It is without doubt a female of the present species. Most of the teeth are gone, but those which remain are distinctly bifid and due to the shrinkage of the soft parts appear longer than in normal specimens and rather hairlike.

U.S.N.M. 87656. Norfolk, Va. Creek and marshes at James Fishery. W. C. Schroeder. Type of *Mugilostoma gobio*. This is a male 27 millimeters total length, not in very good condition. The soft parts around the mouth are shriveled, causing the teeth to stand out prominently and to appear abnormally long as a single row of ciliform teeth. Because of the shriveling the lower jaw also is abnormally thin and angular and this together with ciliform teeth suggests a mulletlike mouth. In color, pattern and other specific characters, it agrees closely with specimens of similar size of the species under discussion. When directly compared with well-preserved specimens the type appears more slender and the ventral fin is placed distinctly in front of the pectoral base instead of under it, but these differences may well be ascribed to its poor state of preservation—the body being evidently shrunken and the wall of the belly collapsed. Most of the teeth are entire, but when examined with a strong lens a few are already seen to be bifid.

Besides the above-described types, other specimens examined were: U.S.N.M. 81823, Cr. Mindi, Canal Zone, January 14, 1911, Meek and Hildebrand, 2 males, 41 and 42 millimeters; U.S.N.M. 78181, Gordo Paint, Nicaragua, March 7, 1917, C. G. Holland, 1 female 74 millimeters; U.S.N.M. 78136, Jamaica, C. B. Wilson, 16 males, 32 to 51 millimeters; U. S. N. M. 88331, Porto Rico, W. C. Earle, 2 males 31.5 and 72.5 millimeters; U.S.N.M. 88301 and 88323, Barranquilla, Colombia, from marshes having connection with Magdalena River, Dr. H. Hanson, February 27, 1924. The label in the last bottle has the name "volador" written on, this apparently being the common name of the fish.

The types of *Gobius garmani* and *Smaragdus costalesi* which are located in the Museum of Comparative Zoology, have been kindly compared by W. C. Schroeder with material from Louisiana, and he finds that the former are females and the latter is the male of the present species. The teeth of *garmani* are notched and in a single row, while that of *costalesi* are entire and the lower jaw has an inner row of enlarged teeth. The coloration and the proportion of the various parts agree closely with the Louisiana material.

As to *Gobius parvus* Meek, the description does not include an account of the structure of the teeth, and is in general quite inadequate. The figure, however, unmistakably shows the characteristic color pattern of the present species, especially

the two black spots on the base of the tail, one above the other and separated by a median area of a lighter color.

In regard to the status of *Gobius wurdemanni* Girard, it seems that no subsequent author has reexamined the type which has been stated to be lost. Jordan and Eigenmann suggested that it "may have been drawn from a female of the same species [*Gobius lyricus*]." Girard's short description quite fits the female of this species, but it may apply just as well to *Gobionellus boleosoma,* which is much more common on the coast of Texas than *lyricus*, or it may apply equally well to *Gobionellus shufeldti*. Since, however, Girard's typical material of *lyricus* included at least six specimens of *boleosoma*, it is evident that he regarded the latter species as the young of *lyricus*. As for *shufeldti*, that species does not appear to be as common. It is, therefore, quite plausible to assume that *wurdemanni* is the female of *lyricus*. At any rate, since the type specimen has been lost and the question can not be positively settled, it is most expedient to let that name rest in peace in the synonymy of *lyricus*, because such action will least disturb the present-day established nomenclature of the American gobies.

EVORTHODUS

Evorthodus Gill, Pr. Ac. Nat. Sc. Philadelphia, p. 195, 1859.

Genotype: *Evorthodus breviceps* Gill=female of *Gobius lyricus* Girard. Monotypic.

Mugilostoma Hildebrand and Schroeder, Fish. Chesapeake Bay, p. 327, 1928.

Genotype: *Mugilostoma gobio* Hildebrand and Schroeder=juvenile of *Gobius lyricus* Girard. Monotypic.

Small gobies with a moderately elongated body. Scales on body rather large, ciliated. Cycloid scales present on upper part of opercle to about the level of the lower margin of the eye. Antedorsal area with smaller cycloid scales extending to eyes; small, partly embedded scales also present on chest and ventral surface of abdomen. Mouth medium, maxillary narrow and weak in both sexes, not quite reaching posterior margin of eye. Caudal fin moderately elongated and pointed in full grown males, shorter and nearly rounded in females and young of both sexes. Teeth in females and young males in a single row, small compressed, notched, proximate; in full-grown males teeth rather long, somewhat pointed, spaced, their distal margin entire, and with a second row of enlarged teeth in lower jaw behind outer row, four to eight in number; the very young having teeth like the females but with entire margins. First dorsal with 6 spines, second dorsal with 11, and anal with 12 rays. Ventral disk well developed, free, infundibuliform. Shoulder girdle without flaps of skin. Tongue free, with entire edge.

EVORTHODUS LYRICUS

Gobius lyricus Girard, Pr. Ac. Nat. Sci. Philadelphia, p. 169, 1858 (Brazos Santiago, Tex., male).

Gobius wurdemanni Girard, Pr. Ac. Nat. Sci. Philadelphia l. c. (Brazos Santiago, Tex.).

Evorthodus breviceps Gill, Pr. Ac. Nat. Sci. Philadelphia, p. 195, 1859 (Trinidad, female).

Gobius lyricus, Girard, U. S. and Mex. Boundary Survey, Part 2, Ichthyology, p. 25, pl. 12, figs. 4–5, 1859 (Texas).

Gobius wurdemanni, Girard, l. c. (Texas).

Smaragdus costalesi Poey, Mem. Hist. Nat. Cuba, 2: 280 (1856–1858), 1861 (Cuba, male).

Evorthodus breviceps Gunther, Cat. Fish. Brit. Mus., 3: 85, 1861 (Surinam).

Gobionellus costalesi Poey, Rep. Fis. Nat. Cuba, 2: 394 (Synopsis) 1868 (Cuba).

Gobionellus costalesi, Poey, Ann. Soc. Esp. Hist. Nat., 5: 168 (Ennumeratio, p. 126), 1876 (Cuba).

Euctenogobius lyricus, Jordan and Gilbert, Bull. U. S. Nat. Mus., 16: 633 (1882), 1883.

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Gobius lyricus, Jordan and Eigenmann, Pr. U. S. Nat. Mus., 9: 496, 1886,

Gobius garmani Eigenmann and Eigenmann, Pr. Col. Ac. Sci. (2 ser.), **1**: 61, 1888 (Dominica, Fort de France, Martinique, St. Kitts; female).

Gobius lyricus, Eigenmann and Eigenmann, l. c. p. 63 (Cuba; St. Kitts, male).

Gobius lyricus, Evermann and Kendall, Bull. U. S. Fish Comm., **12**: 117 (1894), 1892 (Galveston).

Gobius stigmaticus, Evermann and Bean, Rep. U. S. Fish Comm., p. 247 (1896) 1898. (Indian River Inlet, Fla. Specimen reexamined.)

Gobius parvus Meek, Publ. Field Columb. Mus. Chicago (Zool. ser.), **3**: 121, pl. 31, 1902 (Vera Cruz, Mexico).

Evorthodus breviceps, Regan, Pr. Zool. Soc. London, p. 393, 1906 (Trinidad).

Evorthodus breviceps, Jordan and Richardson, Pr. U. S. Mat. Mus., **34**: 20, fig. 2, 1908 (Tampico, Mexico).

Gobionellus lyricus, Meek and Hildebrand, Publ. Field Mus. Nat. Hist. (Chicago) (Zool. ser.), **15**: 880, 1928 (Mindi, Panama).

Mugilostoma gobio, Hildebrand and Schroeder, Fishes of Chesapeake Bay, p. 327, 1928 (Norfolk, Va., juvenile).

This species of goby is readily recognized in the field as well as in the laboratory by two characteristic dark spots on the base of the caudal fin, one above and one below, separated on the mid line by a yellowish area. These spots are frequently more or less confluent either with each other or with other blotches on the caudal peduncle, but the characteristic pattern is readily recognizable in every case and is present in both sexes at all stages of growth from 15 millimeters and larger (15 millimeters being the smallest specimen examined).

Body elongate; snout obtuse in front; mouth nearly horizontal, subinferior, the upper jaw being longer; gape entirely below level of eye; maxillary extending to vertical through middle or nearly to posterior margin of eye; lower jaw of female rather thin and frequently somewhat angular in front, this character sometimes being rather striking in specimens preserved with their mouths open, or in those having the soft part partly shrunken; the lower jaw heavier and more rounded in the grown male. Caudal fin rather long and pointed in male, shorter and nearly rounded in female; second to fourth rays of first dorsal quite long and filamentous in full-grown male, sometimes nearly reaching the caudal when laid back; only slightly filamentous in female, not reaching past fourth ray of second dorsal; ventral somewhat longer and dorsal and anal somewhat higher in male. Anal papilla in male an elongate pointed flap, in female a fleshy bulbous tubercle. The changes in the structure of the teeth with sex and age described above.

The fundamental color pattern on the body may be stated to consist of a series of six blotches along the mid line of the sides and another series of blotches along the back placed over the interspaces of the median series. All of the blotches are more or less coalescent producing a rather irregular mottled appearance, but in some specimens the two series of blotches may be vaguely discerned; a number of vertical narrow bars frequently more or less distinct on lower half behind vent, in medium sized or large specimen, and are especially well marked in large males. Three or four short oblique streaks below the eye. Two characteristic dark blotches on base of tail, separated by a median yellowish area, as described above. Dorsals, caudal, and pectoral in females and young males streaked with rows of small spots; in large males the spots on the dorsals being fewer, confined to the basal third, more prominent, somewhat larger, and frequently more or less ocellated with white, especially in largest males. Ocellated condition of spots especially marked on first dorsal. First dorsal with irregular black blotches in addition to spots, one blotch on middle extending on back. In full-grown males the caudal becomes uniformly dusky with two longitudinal rose red bands in life, one above and one below the mid line; the upper band usually

having two small black spots one below and a little behind the other. These bands become whitish in preserved specimens. They usually appear in specimens of 40 to 45 millimeters, but are sometimes indistinct even in larger individuals. Anal more or less dusky, especially in males, with a whitish margin. Ventrals plain in females, dusky in males. Base of pectoral marbled with greenish and bluish metallic shades in life, mottled dark in preserved specimens.

The material from Panama, Jamaica, and Porto Rico shows that the chief secondary sexual characters of the male, namely, the elongation of the anterior rays of the first dorsal, the inner band of the teeth in the lower jaw, the unnotched condition of the teeth, the elongate caudal, and the two red bands on the caudal fin, appear when the fish is on the average smaller than those from the northern coast of the Gulf of Mexico. Evidently, the fish matures earlier in tropical waters, but no specific differences have been noted.

This species is known at present from Chesapeake Bay to Surinam. It is quite common on the Gulf coast of the United States and also appears to be common generally throughout the West Indies. It is not now known to be common on the Atlantic coast of the United States, only two specimens having been examined—one from Chesapeake Bay and the other from the Indian River inlet in Florida—but more intensive collecting on the coast of the Southern States may reveal its presence there in considerable numbers. In the author's experience on the coast of Louisiana, while common where it does occur, it was rather localized to a few salt-water ponds. It evidently needs a certain ecological environment for its existence. It was not obtained in seining open beaches. It was found chiefly in two marshy lagoons connected with Barataria Bay, at the east end of Grand Isle and at Rasor Island (the latter is known on hydrographic maps as Queen Bess Island). These lagoons, at low tide, are reduced to mere ponds disconnected from the main body of water. The bottom is muddy.. At the first couple of drags of the seine these fishes would not be captured at all or but a few would be taken; but after the water was muddied by dragging the seine back and forth, they would be taken in considerable numbers.

TABLE 1.—*Measurements and counts of Evorthodus lyricus, and E. minutus* [1]

E. LYRICUS

Sex	Total length	Standard length	Depth	Head	Eye	Snout	Maxillary	Inter-orbital	Post orbital part of head	Ante-dorsal distance	Caudal peduncle	Length of ventral	Origin of ventral to anal	Caudal	Spinous dorsal	Soft dorsal	Anal	Scales	Locality
Female	29.5	22.3	20.2	26.9	8.5	5.8	9.9	1.8	15.3	35.0	11.7	22.4	28.7	33.6	6	11	12	------	Grand Isle, La.
Do	40.2	31.0	24.2	26.5	7.5	7.7	9.7	3.5	15.5	35.5	10.9	21.9	28.4	31.3	6	11	12	------	Do.
Do	57.0	42.8	26.9	26.2	7.1	7.9	10.8	3.7	14.7	36.2	12.2	25.5	31.5	32.9	6	11	12	32–9	Do.
Do	57	45.0	25.7	25.1	8.0	6.7	9.8	2.2	15.3	35.3	11.8	-----	34.7	-----	6	11	12	------	Trinidad, West Indies, Type of E. breviceps.
Do	67	50.0	24.8	26.0	7.6	8.0	10.4	4.6	15.2	35.6	12.8	21.0	32.8	33.0	6	11	12	32–10	Grand Isle, La.
Do	71	54.3	21.2	25.0	7.5	7.7	9.8	3.7	13.3	33.1	11.6	22.6	33.0	-----	6	11	12	------	Indian River, Fla.
Male	27	22.0	17.3	26.8	8.2	5.5	10.5	2.7	15.9	34.1	10.0	20.5	32.7	-----	6	11	12	------	Norfolk, Va., Type of M. gobio.
Do	35	26.1	19.2	26.4	8.4	7.7	11.1	3.4	15.3	33.0	11.9	24.5	28.7	34.5	6	11	12	------	Grand Isle, La.
Do	41	29.0	22.4	25.2	8.6	7.6	11.0	3.4	15.5	34.1	11.0	25.2	30.7	42.4	6	11	12	29–10	Mindi, Canal Zone.
Do	45.6	33.4	24.0	26.1	7.8	6.9	9.9	3.3	15.3	33.8	12.3	24.6	28.1	38.3	6	11	12	------	Grand Isle, La.
Do	56.5	41.4	24.2	26.6	8.0	7.7	11.8	3.4	15.5	34.7	13.3	24.2	29.2	36.7	6	11	12	30	Do.
Do	77.0	57.0	24.6	24.9	7.0	8.4	11.1	3.0	14.4	32.3	12.5	27.2	30.0	35.1	6	11	12	30–9	Rio Brazos, Tex., Type of G. lyricus.
Do	79	56.0	23.3	25.5	6.3	8.9	10.7	4.1	14.8	31.9	12.3	24.6	28.1	41.5	6	11	12	31–10	Grand Isle, La.

E. MINUTUS

Sex	Total length	Standard length	Depth	Head	Eye	Snout	Maxillary	Inter-orbital	Post orbital part of head	Ante-dorsal distance	Caudal peduncle	Length of ventral	Origin of ventral to anal	Caudal	Spinous dorsal	Soft dorsal	Anal	Scales	Locality
Female	30.5	24.3	25.5	24.7	8.6	7.4	9.1	4.1	14.8	37.4	14.0	21.4	30.9	-----	6	11	12	------	Corozal, Canal Zone, Type of E. minutus.

[1] The numbers given are percentages of the standard length. In the counts of the second dorsal and anal rays, the first single ray was included, while the last two which are invariably approximated at their base have been enumerated as one. The scales have been counted from the upper angle of the base of the pectoral to the base of the caudal and in a transverse row from the origin of the anal backward to the base of the dorsal.

EVORTHODUS MINUTUS

Meek and Hildebrand, Publ. Field Mus. Nat. Hist. (Chicago) (Zool. ser.) **15**: 870, pl. 84, 1928 (Corozal, Panama).

This species has been described from three small specimens obtained on the Pacific coast of Panama. I have reexamined the type, a well-preserved female, 30.5 millimeters long, in the National Museum. It is somewhat chubbier and deeper-bodied than the average specimen of the same size of *lyricus* from the Atlantic coast, but no other essential differences are noted. The teeth have been correctly stated in the original description as being entire, while specimens of that size from the Atlantic coast, as a rule, already have the teeth notched. The determination of the difference in dentition between this species and *lyricus* from the Atlantic coast, if any, as well as the degree of difference in proportional measurements must wait until a series of adults are obtained. The measurements of the type have been included in the above table for the purpose of comparison. No other species of this genus is known at present.

EFFECTS OF PULP MILL POLLUTION ON OYSTERS [1]

By A. E. HOPKINS, Ph. D., *Aquatic Biologist*, PAUL S. GALTSOFF, Ph. D., *In Charge, Oyster Fishery Investigations*, and H. C. McMILLIN, *Junior Aquatic Biologist*

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I. THE EFFECT OF SULPHITE WASTE LIQUOR ON THE OYSTER (*OSTREA LURIDA*)

By A. E. HOPKINS

INTRODUCTION

The purpose of the present investigation, which was undertaken at the request of the oystermen of Shelton, Wash., was to throw some light on the difficulties faced by the oyster industry in Oakland Bay, where oyster culture has suffered a setback amounting to almost complete cessation. Oysters are adapted to life in inshore waters which are considerably diluted by land drainage and where the conditions of their natural habitat may be subjected to changes caused by the addition of waste matter of wide variety. Suspicion had been directed toward the waste liquor poured into the bay from a pulp mill established on Oakland Bay in 1927, for in this industry there is necessarily a large amount of commercially worthless material remaining after the pulp is removed from the wood. Inasmuch as little experimental work has been done which can serve as a basis for predicting the effect on the oyster industry of waste matter discarded from the factories, it is important to determine just what possible effect certain specific waste substances may have upon the life of the oyster. It was expected that the present investigation would show what effect pulp-mill wastes may have on the oyster and would serve as a foundation for general

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recommendations concerning the location of pulp mills in the vicinity of oyster grounds.

A laboratory was established on Oyster Bay, near Olympia, Wash., and equipped with running seawater.[2] At this place the water was probably not contaminated with the waste liquor to any great extent, for Oyster Bay is a considerable distance from Oakland Bay.

SULPHITE WASTE LIQUOR

Although in certain cases sulphite pulp mills have established plants for the recovery of chemicals and the manufacture of by-products from the waste liquor, this is the exception rather than the rule in the United States. Mills are most often located on fresh-water streams into which all waste matter is dumped after little or no treatment to prevent possible damage to aquatic life. This method of disposal is generally inadequate because of the great amounts of waste matter produced.

In the manufacture of pulp by the sulphite process the chips of wood are cooked under pressure in a solution consisting primarily of calcium bisulphite with an excess of sulphurous acid. Something over half of the constituents of the wood go into solution to form the waste liquor while the fiber remains. The liquor contains, in addition to the substances in the original cooking solution, though changed somewhat in the process, nearly all of the noncellulose constituents of the wood. The specific gravity of the liquor from the digester at the end of the cooking process is about 1.05, and may vary from 1.045 to 1.055. It is a dark reddish-brown liquid, rather syrupy in consistency.

The general nature of the liquor is shown by the following results of an analysis of a sample of liquor of specific gravity 1.0425 by Bryant, as stated by Sutermeister (1929, p. 233):

Constituents	Grams per liter	Pounds per ton pulp	Constituents	Grams per liter	Pounds per ton pulp
Total solids	115.00	2,999	Total sulphur	7.83	204
Loss on ignition	105.36	2,748	Sulphur as SO_3	.76	20
Ash	9.64	251			

The actual solids in solution amount to more than the pulp produced. The most of these substances are organic, and there is no limit to the possible number of compounds present. The variety of components is indicated in the figures given by Sutermeister (1929, p. 234), after Klason, for the waste liquor remaining from production of a ton (2,202 pounds) of dry pulp: 600 kilograms lignin, 200 kilograms sulphur dioxide combined with lignin, 90 kilograms CaO combined with lignin sulphonic acid, 325 kilograms carbohydrates, 15 kilograms proteins, and 30 kilograms rosin and fat.

Complete analysis of such a highly complex mixture of organic compounds is extremely difficult. While the lignin-containing compounds make up the bulk of the solids, other compounds of a complex nature may be present in such minute amounts as to be overlooked. Most of the analytical work which has been done refers to the question of manufacture of by-products. The sugars and related

[2] The Bureau of Fisheries is indebted to State Senator J. H. Post of Thurston County, Wash., for allowing the use of his culling house as a laboratory and for furnishing a Kohler electric plant and various pumps, motors, and other electrical equipment. We also wish to express our appreciation to C. R. Maybury, director of the Washington State Department of Fisheries and Game, and to C. R. Pollock, supervisor of fisheries of the same department, for furnishing certain laboratory equipment and otherwise cooperating in this investigation.

substances in the liquor have been investigated from the standpoint of manufacture of commercial alcohol, which is often carried on in Europe. According to Sutermeister (1929, p. 234), Krause made the following determinations for liquor from autumn-cut wood treated by the Ritter-Kellner process; the results are expressed as percentage: Furfural, 0.02; pentosans, 0.29; hexosans, 0.49; total sugars, 1.47; pentoses, 0.41; mannose, 0.48; levulose, 0.25; galactose, 0.21; and dextrose, trace.

Sutermeister (1929, p. 233) summarized a work by Walker as follows:

"Among the constituents present he mentions sulphur dioxide, sulphur trioxide, free sulphur, calcium and magnesium lignin sulphonates, pentoses and pentosans, mannose, dextrose, galactose, free furfural, traces of vanillin or vanillinlike body and small quantities of terpenelike substances." Citing another work, Sutermeister wrote: "Hoenig claims that no organic acids except formic and acetic are present and that the ratio of these is 1:1.56. He finds 2.15 to 9.08 grams of volatile acid per liter." Further (Sutermeister, p. 235); "The waste liquor, according to Walker, yields brominated and chlorinated products; it contains active carbonyl and methyl groups and is a strong reducing agent." Methyl alcohol, acetone, aldehyde, acetic and formic acids, and a brown oil, part of which is cymene, were found in condensed digester vapors by Bergström, according to Sutermeister. The same author stated that 8 to 10 kilograms of methyl alcohol are produced per ton of pulp. Sutermeister (p. 241) stated: "Other substances which it has been proposed to recover from the waste liquor are antiseptic materials, calcium sulphate, calcium sulphite, coniferin, cymol, acetic acid, furfural, levulinic acid, oxalic acid, sulphur, turpentine, lignorosin, vanillin, etc."

In addition to the wide variety of substances mentioned above, the liquor contains all of the inorganic components of the wood. These would be in relatively small amounts, but might be of some significance with regard to aquatic animals. These analyses appear not to indicate definitely any particularly toxic substances which might be expected to exert an unfavorable influence upon aquatic life. However, the wide variety of substances present suggests the possibility that many other compounds may be in the liquor in small amounts which would be difficult to detect chemically. It has been stated that workmen in sulphite mills often drink the liquor for its laxative effect, which indicates that it certainly is not a violent poison to man.

Usually pure digester liquor is not dumped into the bodies of water on which mills are located. In "blowing" a digester and separating the pulp from the waste liquor enough water is used to reduce the specific gravity of the liquor from 1.05 to between 1.01 and 1.02. Just after a "blow" the liquor is likely to be of high specific gravity, which is reduced in the liquor which follows by dilution. Such heavy liquor on entering a turbulent stream is thoroughly diluted, but if it enters a relatively still body of water would be expected to sink to the bottom.

Because of its great excess of sulphurous acid, the liquor is highly acid, a characteristic which is not conducive to favorable aquatic conditions. However, in the case of salt water in particular, the acidity does not last long, partly because of direct neutralization and partly due to loss of sulphur dioxide into the air.

In addition to the liquor, there is a considerable quantity of pulp fiber too small to be held in the separators, which must be disposed of as waste. Typically, this settles to the bottom of the body of water into which it is thrown and is very slowly decomposed. This is an important polluting material in some places, especially in streams, where it may interfere with the feeding and breeding of fish. The bleach fluid, containing chlorine compounds primarily, is also a constituent of the wastes from sulphite mills.

In some cases the waste liquor is treated to neutralize acidity by passing it over limestone before allowing it to go into the water. Running the liquor into a pond or settling basin from which it flows into the river has been found advantageous.

Experiments of this nature by the Wisconsin State Board of Health in 1927 succeeded in markedly reducing the oxygen demand of the liquor.

Experimental observations on the effect of sulphite liquor on aquatic organisms have been made in certain cases, but most of the reports on the subject consist of surveys made primarily from the standpoint of dissolved oxygen. Also these works have been concerned with fresh-water streams and lakes and not with salt-water bays and estuaries. It has been well established that fish avoid the waters which are polluted with sulphite wastes, but it appears that this is largely due to depletion of oxygen in the water rather than to any great toxic effect.

That sulphite liquor exerts a germicidal action was shown by Levy (1905), according to Phelps (1909). He found that a 5 per cent solution of sulphite liquor in water highly polluted with sewage reduced the number of bacteria by 86 per cent in 6 hours, while a 10 per cent solution killed all bacteria within the same length of time. Presumably this effect is primarily directly toxic, for the highly polluted water was probably very deficient in oxygen even without the liquor. Levy suggested that the harmful effect of the liquor on fish might be due to removal of free oxygen from the water.

In a series of experiments on the effect of waste liquor on perch, bass, and brook-trout fry, March (1907) found that in solutions up to 1:200, without aeration, the specimens died, but that neither perch nor bass were killed after 27 days exposure to an aerated solution of 1:50 (specific gravity of stock liquor 1.028 at 11° C.). This would appear to indicate that death had been produced by insufficient dissolved oxygen. Later, however, March (1908, p. 896) stated, "A sample experimented with by the writer had little or no reducing action on the dissolved oxygen in the water, and it is likely that it kills by its direct action alone."

Whipple (1922) called attention to the filamentous fungi which thrive in sulphite polluted water which may in a secondary manner make the water unfit for fish life.

The review of experimental data by Suter and Moore (1922) pointed out that the harmful effect of sulphite liquor on fishes is limited to fairly concentrated solutions, in general within 1:200. More recent work by Nightingale and Loosanoff (1928) on the effect of liquor on early stages of salmon indicated that although lower concentrations may be fatal, the effect primarily is due to low oxygen content. Low concentrations produced an apparently chemical effect on the scales of fry.

Recent investigations of the fish life in the Ausable River by Carpenter (1930) showed that fish avoid sulphite polluted water even though the most contaminated water of the river was about 35 per cent saturated with oxygen (Faigenbaum, 1930).

The results of Knight (1901) differ from those of other workers in concentrations required to kill fish. The sulphite "waste water" which he used was of specific gravity 1.00005, which presumably represents digester liquor diluted with 1,000 parts water. Yet a solution made up of 1 part of this to 9 parts water was fatal to trout, white perch, sunfish, and rock bass. The effect may have been due to the very high acidity of the waste water. It is also not impossible that the potency of the waste liquor depends upon the kind of wood employed in the mill.

Because of the usual location of pulp mills on streams, there has been no pressing need of determining the effect of sulphite liquor on oysters. Most of the observations indicated in the foregoing account are probably not applicable to marine organisms and to oysters in particular. In the first place oysters are immobile and can not avoid unfavorable water by changing their position, as can fish. Also, it

is probable that the sensitivity of oysters to foreign substances may be decidedly different from that of fishes.

The problem of the effect of factory wastes on the aquatic life in streams is very different from the problem which grows out of the dumping of such wastes into bays and estuaries where oysters occur. While the flowing water of a stream constantly carries away fluid wastes, the more sluggish waters of a tidal basin are liable to absorb such substances and retain them. In the latter case, the tidal currents do not readily eliminate pollution. In a body of water of this kind, oysters would be subjected to the foreign substance more continuously and for longer periods of time.

Sulphite liquor contains a large quantity of calcium sulphate in solution. When the liquor is neutralized with sodium hydroxide this appears as a precipitate, relatively insoluble in neutral fresh water but quite soluble in sea water. That the calcium sulphate may be partly responsible for the toxicity of the liquor is suggested by the observations of Oku, Ito, and Fujita (1901). They found that Japanese oysters died in aerated solutions of calcium sulphate in sea water in concentrations of 0.633 grams per liter and above. The lowest concentration which would produce death was not determined. Oysters 2 and 3 years old were found to be more susceptible than 1-year-old specimens. In a later publication by Oku (1904), it was stated that oysters died as a result of the presence of calcium sulphate only in relatively warm water, for no deaths occurred in a similar series of tests made in winter. A further statement in this publication was to the effect that meats of oysters in ordinary sea water contained less copper than those kept for some time in solutions of calcium sulphate in sea water. This is an interesting suggestion but further evidence would be required to demonstrate the significance of the observation.

MATERIAL AND METHODS

For the experimental work Olympia oysters (*Ostrea lurida*) were taken fresh from the dikes of the Blass Oyster Co. in Oyster Bay. These specimens were selected because of their excellent condition, showing that they were relatively normal oysters and not obviously suffering from any cause as is the case with Oakland Bay oysters. The oysters used were all of approximately the same size, about 4.5 to 5.5 centimeters long by about 3.5 to 4 centimeters wide, and the same age, 4 to 5 years. Relatively large specimens were employed to facilitate the recording of shell movements on the kymograph. That they were in good condition is shown by the fact that no control specimens died during experimentation.

For laboratory use, liquor, through the courtesy of D. B. Davies, manager of the Rainier Pulp and Paper Co. at Shelton, Wash., was drawn directly from the digester at the end of a cook into a keg, in which it was transported and kept in the laboratory.

The apparatus employed for the experiments is described in detail below. Most of the tanks, aquaria, etc., used were made of clear, transparent celluloid plates, one-eighth inch thick. Parts of any such piece of equipment were sealed together with a solution of the same celluloid in acetone. The material is well suited to such work and oysters live well in equipment made of it.

A diagram of the apparatus used in the laboratory to produce a running mixture of liquor and sea water is presented in Figure 1. It is essentially an arrangement of constant levels whereby the rate of flow due to gravity is kept constant. In the 5-gallon carboy (*A*) was a mixture of liquor and sea water in proportions 1:4, 1:9, or 1:19, depending upon the final concentration desired. The tube in the mouth of the bottle projected into the jar (*B*) in such a manner as to cause liquor to flow down when the

level of the fluid in the jar fell low enough to expose the tube. The distributing chamber (*D*) was on a lower level and the fluid was admitted to it at a nearly constant rate through the tube (*C*) which was fitted with a stopcock for regulating the rate of flow. The overflow space (*E*) at the proximal end of the distributing chamber was sufficiently large to prevent the level of the fluid from rising any higher. Variation of the level of fluid in this chamber might therefore be downward, due to stoppage of tube *C*, but not upward. Attached by adjustable clamps on vertical bars to the wall of chamber *D* were four dripping chambers (*F*), only one of which is shown in the diagram.

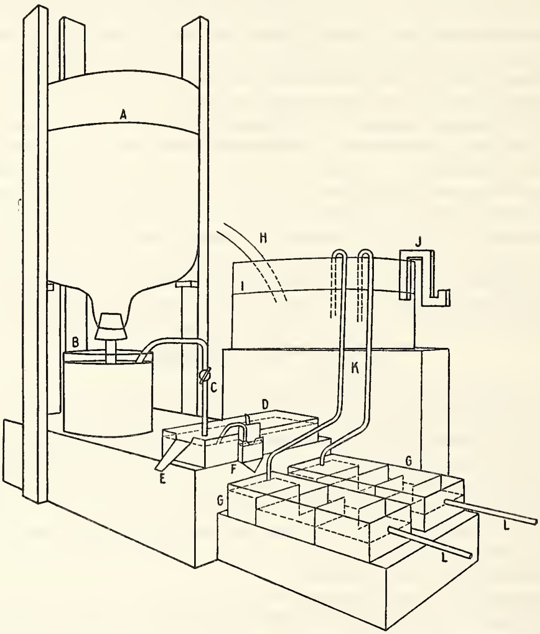

FIGURE 1.—Diagram of the apparatus used to deliver running mixtures of sea water and sulphite liquor in constant proportions. See text for full description

In Figure 2 the dripping chamber is shown in detail. The inside dimensions were: Height, 4.5 centimeters; width, 2.5 centimeters; and thickness, 1.5 centimeters. In the top of the front wall a V-shaped opening (*C*) allowed the fluid to spill over and run down, where it dripped from the extending tip (*D*). The back wall (*B*) was extended upward to allow attachment to the fixed upright (*E*). Fluid from the distributing chamber (*F*) passed through the glass tube (*A*) into the dripper, from which it overflowed through *C* and dripped into the mixing chamber (fig. 1, *G*).

In Figure 3 is a detailed diagram of the mixing chamber. This was 15 centimeters long, 5 centimeters wide, and 6 centimeters deep, and consisted of a small

chamber (*A*) separated from the larger one by a wall (*B*), 4.5 centimeters high. Baffle plates (*C* and *C'*), approximately equally spaced, divided the chamber incompletely into several parts. Both sea water and liquor solution flowed into chamber *A*, where they were well mixed. The resulting solution flowed over plate *B* and back and forth among the baffle plates, becoming thoroughly mixed, until it flowed out through the tube (*D*) into the aqarium containing the experimental specimens.

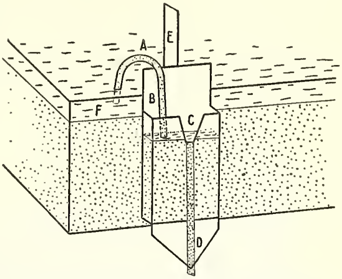

FIGURE 2.—Diagram of the dripping chamber from which liquor dripped at a constant rate into the mixing chamber. See text for full description

The rate of flow of sea water was fixed as shown in Figure 1. Through the tube (*H*) water continuously flowed more rapidly than was necessary into the 10-gallon aquarium (*I*). A large constant-level siphon (*J*) of celluloid, having a cross-section area of about 5 square centimeters, maintained a constant level in the aquarium jar in spite of minor variations in the rate of flow of entering water. Glass and rubber tubes of 3 to 5 millimeters inside diameter led from the aquarium to the mixing chamber (fig. 1, *G;* fig 3, *A*) into which the liquor was dripping.

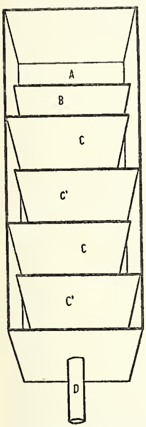

FIGURE 3.—Diagram of the mixing chamber (fig. 1, *G*) in which water and sulphite liquor were thoroughly mixed before entering the aquaria. See decription in text

The experimental and control specimens were contained in a tank (fig. 4) consisting of three separate but adjoining compartments (*A*, *B*, *C*), each having a capacity of about three liters. In the front wall of each compartment an overflow space (*D*) was cut to allow continuous overflow without passing of the fluids from one chamber into another. A tube from a mixing chamber led to each of the two end compartments, while another tube led from the aquarium jar (fig. 1, *I*) into the middle compartment. The two end chambers contained running mixtures of sea water and sulphite liquor in known proportions, while the middle chamber contained pure, running sea water as a control.

Fresh oysters were mounted on a plaster of Paris base to hold them in a fixed position and at the same time not interfere with their natural functions. Two such specimens were placed in each of the three experimental compartments. (Fig. 4, *A*, *B*, *C*.)

Records of the shell movements were kept continuously by means of a kymograph. A slender strip of celluloid (fig. 4, *E*) rested upon the shell of each specimen and was movably attached at its upper end to a horizontal celluloid lever (*F*). A short wire at the distal end of the lever came into contact with the smoked, slowly moving kymograph paper. All six specimens of a series were arranged to write their records on the same paper.

The kymograph carried a paper about 2 meters long and moved at a constant rate of about 31 millimeters per hour. Usually after the paper had made a complete circuit the drum was slightly lifted and another circuit made, the levers writing in between the lines made the first time.

Changing a paper occupied only 15 minutes, during which time the loss of records is insignificant. After fixing a completed paper in shellac it was marked off into hourly and daily periods and the records analyzed.

During most of the experiments thermograph records were kept of the temperature of the water in which the specimens were immersed. The bulb was inserted into the middle chamber with the control specimens, for the metal might be attacked by the liquor in the other chambers and so introduce a source of error. In the three experimental compartments the temperature was so nearly the same that the maximum difference observed was hardly over 0.2° C.

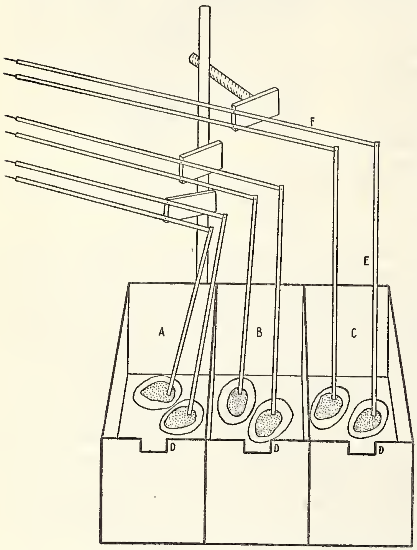

FIGURE 4.—Diagram showing the arrangement of connected aquaria, containing experimental (end chambers) and control (middle chamber) specimens connected to levers which recorded shell movements on the kymograph. Complete description in text

In the winter weather, when the pumped water was around 5° C. or lower, the water was heated slightly before entering the large aquarium jar. It passed through a lead coil which was immersed in a pail of water under which a kerosene flame burned. The resultant water in the experimental chambers was usually of about 15° to 17° C., or high enough to permit the oysters to feed and grow.

A fresh supply of sea water was maintained by means of an automatic pump, which pumped water at intervals of one to two hours into two 50-gallon oak barrels. The laboratory (fig. 5) was in a cove which formed a part of Oyster Bay, but which at low tide was well above the level of bay water. The cove was diked to retain a depth of 2 to 4 feet of water at low tide. At high tide the bay water entered the cove, so that the cove water did not markedly differ from the bay water in salinity.

The supply of liquor and sea water mixture in the 5-gallon carboy was replenished whenever necessary. This amount lasted for from one to three days, depending upon the rate of flow.

Most of the experiments were carried on without first neutralizing the liquor. The pH of the resultant solution was consequently lower than that of the sea water. That the effects observed were not due to acidity was shown by a control series.

GENERAL CONSIDERATIONS

In Oakland Bay four chief abnormal characteristics of the oysters have been observed since spring, 1927. In the first place practically no setting occurred, and consequently no seed oysters were obtained. In addition, many oysters died on

Figure 5.—Photograph of culling house used as laboratory

the grounds. (See accompanying report of McMillin.) Further, the oysters remaining were extremely thin and watery, showing none of the rich white meat of normal specimens. Also, new shell growth was seldom to be observed. These four characteristics may be reduced to three for the present purposes by combining lack of reproduction with thinness of meats, for the former is probably largely a consequence of the latter. However, it is probable that liquor may be highly toxic to oyster larvæ. It would be of considerable significance to determine whether these conditions could be reproduced among oysters in the laboratory by adding sulphite liquor to otherwise favorable water. In the following pages are descriptions of experiments designed to determine the potency of the liquor in these respects.

A short description of the feeding activities of oysters is necessary to make the experimental results clear. (See Galtsoff, 1926, 1928.)

The oyster shell consists of two halves, or valves, connected by an elastic hinge which holds the valves several millimeters apart. The adductor muscle of the oyster is attached to both valves and, by contracting, closes them. Feeding can take place only when the muscle is relaxed and the valves open, for only then can the food-bearing water enter. The four gills of the oyster force the water through themselves by ciliary action (see accompanying report of Galtsoff) and filter out the food organisms, which are then swallowed. It is clear that under otherwise identical conditions two oysters may be together, one remaining open most of the time and the other remaining closed most of the time, the former would have opportunity to take in more food than the latter and would consequently be expected to store up a larger reserve food supply, which in the oyster is chiefly glycogen. The so-called fat oyster contains a large supply of glycogen. Relative absence of this reserve causes an oyster to be thin and watery, as has been the case with the Oakland Bay oysters.

Any agent which reduces the number of hours per day that the valves of oysters remain open at the same time reduces the number of possible feeding hours. Such oysters would be expected to store up less reserve food. The present experiments were designed to show whether the presence of sulphite liquor causes oysters to reduce their possible feeding time by remaining closed longer than specimens in uncontaminated water.

Following are detailed descriptions of the behavior of each experimental specimen. In general, a single series consisted of two experimental pairs of oysters, in different concentrations of liquor, and one pair of control specimens in uncontaminated water. Because of large individual variations it is difficult to express the results in any manner other than as separate descriptions. The series are organized according to concentrations of liquor employed, but there is considerable overlapping.

Concentrations of liquor in water are stated as parts per thousand. It must be emphasized that the stated concentrations represent the mixtures which the apparatus was standardized to deliver, and that any variations from this would be due to stoppage of the liquor tubes, causing temporarily a lower concentration. The water system was readily kept constant but, because of suspended matter in the liquor, there was an occasional slowing in its rate due to accumulation of particles in the small opening of the stopcock. This was reduced to a minimum by frequent cleanings, but any error due to this would tend to make the concentration lower, not higher, than that stated.

The experimental specimens were tested for a short time in water alone before the liquor was run in. When the experimental fluid started this was allowed to run into the chamber already full of pure water, which it slowly replaced.

The kymograph records were fixed in shellac, and then marked off into hourly periods for recording the results. At times one of the levers would not be close enough to the paper to write the record, and several hours of records might thus be lost. In such a case the number of hours per day that the specimen was open was computed for the period of existing records and then calculated on the basis of the 24-hour period.

EXPERIMENTS WITH ACID LIQUOR

Experiment No. 1 (6 parts per thousand, October 15 to 19, 1929).—One specimen was in each of the three experimental tanks. The first and third were controls and the

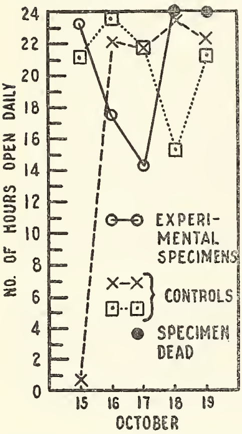

FIGURE 6.—Graph showing the number of hours per day which each specimen employed in experiment No. 1 was open. One specimen was subjected to sulphite liquor solution (6 parts per 1,000), while two were controls in pure water

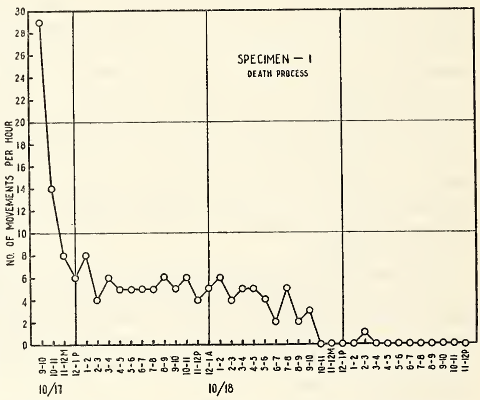

FIGURE 7.—Graph showing the cessation of activity of the liquor-treated specimen in experiment No. 1. The number of closing movements is plotted for each hour from beginning of gaping of the shells until movement had ceased

second, experimental. All specimens were in pure, running sea water on October 15 and up until 7.50 p. m. on the 16th, when liquor was started dripping into the mixing chamber which supplied the experimental oyster. In this case water was flowing at the rate of 134 cubic centimeters per minute and pure liquor was entering at 0.8 cubic centimeters per minute making a final solution of 6 parts per thousand. The pH of the solution in the experimental tank was between 5.8 and 6.1, while that of the control water was 7.7. During the test the temperature of the water in all tanks fluctuated between 10° and 14° C.

In Figure 6 are shown graphs of the number of hours per day that each specimen remained open. There is little difference between the specimens in this respect, but while the two controls remained open and highly active, the experimental specimen

became less and less active until it remained open and entirely motionless on October 18. This is characteristic of a dead or dying oyster. A graph (fig. 7) is presented to show the slow reduction in the number of shell movements, or adductor muscle contractions, per hour. When movement had definitely ceased the specimen was considered dead, and opened. The adductor muscle was flabby and soft, instead of hard as usual when cut. The heart was not beating but reacted slightly to mechanical stimulation. In no other case did death follow so quickly (48 hours) after introduction of the liquor.

It should be pointed out that when a specimen gapes wide open and is unable to close it will quickly be eaten whether dead or alive by small crabs and fish.

Experiments Nos. 16 and 17 (February 1 to 20, 1930).—Six specimens were included in these tests: 2 in each of the liquor solutions, and 2 controls in sea water alone. Records were started at 1.10 p. m., February 1. On the 1st, 2d, and 3d the temperature of the water used varied from 5° to 8° C. after which the water was heated and showed a maximum variation of from 12° to 18° C., the usual range being 14° to 17° C.

Experiment No. 17 (10 parts per thousand).—Water entered the mixing chamber at the rate of 90 cubic centimeters per minute, while liquor solution (1 part pure liquor to 4 parts sea water) dripped in at the rate of 4.6 cubic centimeters per minute, producing a solution of close to 10 parts per thousand. The pH of the solution in the experiment chamber varied between 4.7 and 5.6. Liquor was started dripping into the mixing chamber with the water on February 3 at 2.30 p. m. and continued until the end of the experiment. Figures 8 and 9 show the results of both experimental and control specimens in hours per day that they remained open. All four specimens were closed most of the time during the first three days. This was probably due to the low temperature of the water at this time.

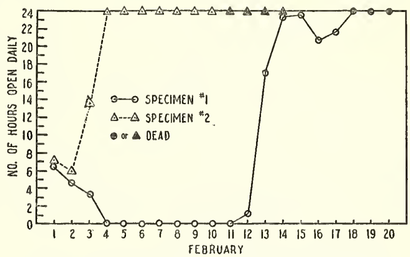

FIGURE 8.—Graph showing the number of hours per day that each specimen in experiment No. 17 (10 parts per 1,000) remained open. The individual difference is striking and shows the longer life of the specimen which remains closed most. Compare with the control specimens shown in Figure 9

From February 4 until death occurred on the 18th, experimental specimen No. 1 (fig. 8) stayed open an average of only 7.7 hours per day. The specimen died after being in the solution for 14 days, during the first eight of which the valves remained tightly closed.

The reaction of specimen No. 2 was decidedly different. It began to gape open (loss of muscle tonus) within two days, and activity became constantly less frequent until the final movement was made on the 13th, nine days after starting of the liquor. In several other cases this individual difference in the reactions to the liquor was observed. Why this should be the case is not clear, but it appears that the specimens which remain closed most of the time live longer than those which remain open in the liquor solutions.

During the period following February 3 the two control specimens (fig. 9) stayed open for a high percentage of the time. From February 4 to 20 specimen No. 3 averaged 23.01 hours per day open, while specimen No. 4 averaged 22.7 hours per

day open. At the end of the experiment the control specimens were as normally active as at the beginning. They both showed a delicate new shell growth at the edge of the valves, which was not the case of the treated oysters. Further, the controls showed that they were feeding for they threw out large quantities of fecal matter, rejected silt, etc., while the experimental oysters did not.

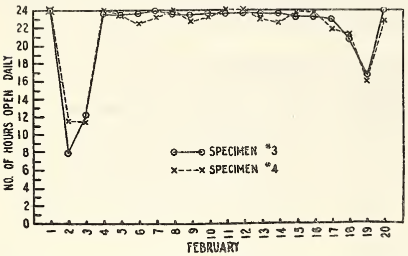

FIGURE 9.—Graph of the daily number of hours open of the control specimens for experiments Nos. 16 and 17. These oysters remained open and active a very high proportion of the time. Compare with Figures 8 and 10

Experiment No. 16 (*5 parts per thousand*).—Water flowed into the mixing chamber at the rate of 124 cubic centimeters per minute, and liquor (1:4) at the rate of 3 cubic centimeters per minute. The concentration of pure liquor to water was 4.84 parts per thousand, which is stated roughly as 5 parts per thousand. The pH of the solution in the experimental chamber varied from 6.1 to 6.5. Liquor was started February 3, at 2.30 p. m. and continued until the end of the experimental series. Specimens 5 and 6 (fig. 10) showed a difference in behavior similar to that of the specimens in experiment No. 17. From February 4 until just before death on the 18th, specimen No. 5 was open an average of 10.4 hours per day. On the 19th this oyster was gaping wide and motionless, having died after 15 days in the solution. Specimen No. 6, from the 4th until the 16th, averaged 22.54 hours per day open, and was dead on the 17th, 13 days after the liquor was introduced. These specimens showed no indication of shell growth and threw out no waste matter to indicate that feeding was going on.

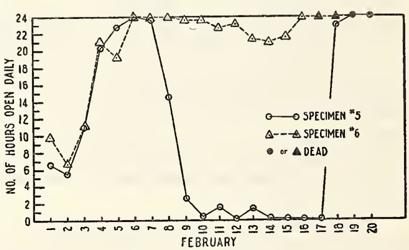

FIGURE 10.—Graph showing the records of two specimens in experiment No. 16 (5 parts per 1,000). The oyster which remained closed most lived longer than the other specimen. Compare with Figure 9 showing the record of controls

Experiments Nos. 18 and 19 (*February 1 to March 3, 1930*).—Records were started on February 1 at 1.45 p. m., the specimens in sea water alone. The pH of the sea water was always about 7.8. The temperature of the water from the 1st to the 3d, inclusive, varied from 4° to 8° C., after which the water was heated and fluctuated from 12° to 18° C., being usually from 14° to 17° C. The stock liquor consisted of 1 part pure liquor to 4 parts sea water.

Experiment No. 19 (*2.4 parts per thousand*).—Water entered the mixing chamber at the rate of 139 cubic centimeters per minute and liquor (1:4) at the rate of 1.67 cubic centimeters per minute. The pH of the solution in the experimental chamber varied from 6.6 to 7.1.

The results with specimens Nos. 1 and 2 (fig. 11) are closely parallel. Specimen No. 1 was open, from February 4 to 27, when it started gaping wide and making a

movement only every few hours, an average of 14.25 hours per day, while for the same period specimen No. 2 averaged 16.14 hours per day open. At the end of the experiment both specimens were gaping wide open and No. 2 had ceased to move. Specimen No. 2 had died after 27 days of treatment. Within one or two days more, at most, judging from the infrequent shell movements, specimen No. 1 would have died. For the purpose of record the latter is considered to have died in 29 days.

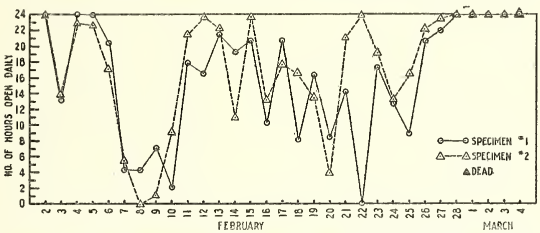

FIGURE 11.—Graph showing the records, in hours open daily, of the two specimens employed in experiment No. 19 (2.4 parts per 1,000). Compare with the controls (fig. 12)

At the same time the control specimens Nos. 3 and 4 (fig. 12) averaged 20.61 and 17.85 hours per day open. Between the 23d and 28th these specimens remained closed a large part of the time. It was suspected that a leak between one of the experimental chambers and the control chamber had occurred. The level of water in the control chamber was raised a little to prevent flow of contaminated water into it, and the specimens again behaved normally. After the experiment had been completed such a small leak was found to have occurred. A small quantity of the liquor

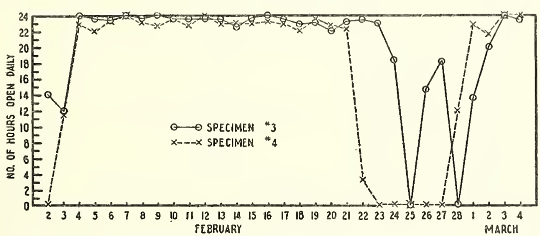

FIGURE 12.—Graph presenting the records of control specimens for experiments Nos. 18 and 19. The low records toward the end were due to a leak from one of the aquaria containing liquor solution. Compare with Figures 11 and 13, experiments Nos. 18 and 19

solution had probably seeped through and produced the striking change in behavior. That this was due to some unusual condition in the control chamber alone is shown by the fact that the records of the experimental oysters show no unusual variations during the same period.

Experiment No. 18 (3.2 parts per thousand).—The rate of flow of water was 123 cubic centimeters per minute and that of liquor solution (1:4) 2 cubic centimeters per minute, producing a final concentration of 3.2 parts per thousand pure liquor to

sea water. The pH of the solution varied from 6.5 to 7.0. Liquor was started at 3.50 p. m. February 3, and continued until the end of the experiment.

The records (fig. 13) show the time of death of the two specimens, as well as the number of hours per day that they remained open. Specimen No. 5, during the period from February 4 until just before it started gaping wide on the 14th, was open an average of 16.62 hours per day and was dead on the 16th, 12 days after the liquor was started. On the other hand, specimen No. 6 averaged 13.32 hours per day open from the 4th until the 24th, after which death occurred following 21 days of treatment.

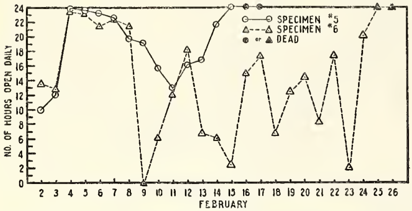

FIGURE 13.—Graph showing the number of hours per day which the specimens in experiment No. 18 (3.2 parts per 1,000) were open. Compare with the controls (fig. 12)

Experiments Nos. 12 and 13 (January 3 to January 10, 1930).—This is an incomplete series due to the fact that the water system was frozen on January 10 and experiments had to be stopped. However, it shows some effect of the liquor in the short time that the test was continued. The water was heated and the temperature varied between 14° and 18° C. The stock liquor solution consisted of 1 part pure liquor to 19 parts sea water.

Experiment No. 13 (3.8 parts per thousand).—The rate of flow of water was 61 cubic centimeters per minute and that of liquor solution 4.66 cubic centimenters per minute, producing a concentration of about 3.8 parts pure liquor per thousand parts water. The pH varied between 6.6 and 7.0.

From January 3 until the 7th at 4.30 p. m., when liquor was started, the specimens were in pure, running water, and both control and experimental oysters (fig. 14) were open a large part of the time. After the liquor was started both experimental specimens showed an immediate reaction. During the three days from the 8th to the 10th, specimen No. 1 averaged 11.46 hours per day open, while specimen No. 2 averaged 18.96 hours per day open. At the same time the control specimens Nos. 3 and 4 were open, respectively, 23.73 and 23.5 hours per day. This is too short a treatment for these averages to be of much significance, but the appearance of the records showing the immediate effect of the liquor on specimens Nos. 1 and 2 is important.

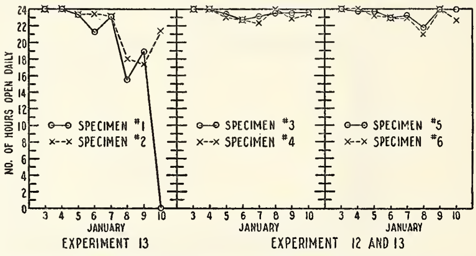

FIGURE 14.—Graphs showing the reactions of the specimens in experiments Nos. 12 (1.8 parts per 1,000) and 13 (3.8 parts per 1,000) and controls

Experiment No. 12 (1.8 parts per thousand).—Water flowed at 116 cubic centimeters per minute and liquor solution (1: 19) at 4.25 cubic centimeters per minute, producing the above-stated concentration in parts of pure liquor per thousand. The pH was usually between 6.8 and 7.1. This concentration is lower than that

used in experiment No. 13 above and the sudden drop in the curves of hours per day open (fig. 14) is not so marked. This is not considered to be conclusive in any respect, and is presented to show that the reaction to relatively low concentrations is not immediate.

Experiments Nos. 20 and 21 (*February 26 to March 30, 1930*).—During these experiments the temperature of the water was maintained, with the exception of a few days, at between 14° and 19° C. The stock liquor solution consisted of 1 part pure liquor to 9 parts sea water. Records were started on February 26 with all specimens in pure running water of pH 7.7 to 7.9.

Experiment No. 21 (*1.3 parts per thousand*).—The rate of flow of water entering the mixing chamber was 90 cubic centimeters per minute and that of liquor solution (1: 9) 1.2 cubic centimeters per minute, resulting in a final concentration of 1.33 parts per thousand. The pH varied between 6.6 and 7.1.

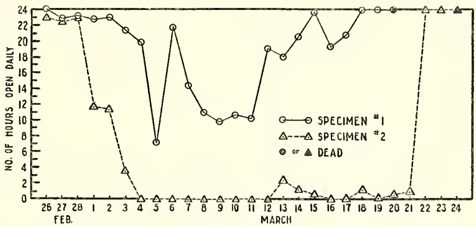

FIGURE 15.—Graph showing records of specimens in experiment No. 21 (1.3 parts per 1,000). The marked individual difference in reaction is clear. Compare Figure 16, showing records of the control oysters

The graph (fig. 15) presents the activity of these specimens in hours per day that they remained open. Before liquor was started the specimens were open about 23 hours per day. Specimen No. 1 did not show an immediate marked change in activity, but the effect appeared after a few days. From March 1 to March 17 this oyster was open an average of 17.15 hours per day. On the following two days it was gaping wide and showing very little movement, ending with death by the 20th,

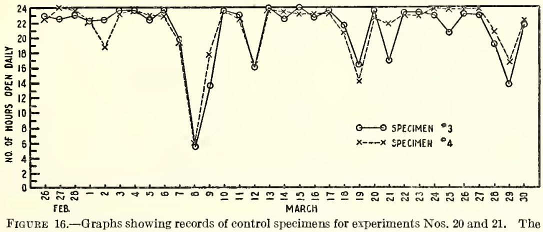

FIGURE 16.—Graphs showing records of control specimens for experiments Nos. 20 and 21. The marked drops in the records were due to sudden temperature changes caused by stopping of heater. Compare with Figures 15 and 17, giving records of experimental oysters

after 19 days of treatment. Specimen No. 2, on the other hand, was not dead until 23 days of treatment, but, from March 1 to 21 averaged only 1.66 hours per day open.

While both of the experimental specimens died, the control specimens (fig. 16) during the entire period of treatment averaged respectively 20.91 and 21.1 hours per day open. At the end of the experiment it was noted that both of these specimens showed new shell growth and that large masses of fecal matter, discarded silt, etc., were left. In the experimental specimens there was no growth and very little refuse matter was thrown out.

Experiment No. 20 (2.0 parts per thousand).—The rate of flow of water was 124 cubic centimeters per minute and that of liquor solution (1 : 9) 2.5 cubic centimeters per minute. The pH of the solution in the experimental chamber was from 6.8 to 7.2. Liquor was started dripping into the mixing chamber on February 28 at 12.30 p. m. On the preceding two days both specimens were open most of the time, but after the liquor was started both remained closed more and more of the time until finally they gaped open and steadily ceased activity. (Fig. 17.) Specimen No. 5 averaged, from March 1 to 15, when it started gaping, 12.93 hours per day open and was finally dead on the 25th, following 24 days of treatment with the solution. Specimen No. 6 also died after 24 days of treatment and during the period from March 1 to 20 remained open an average of only 9.9 hours per day. Compare the records of the two control specimens. (Fig. 16.)

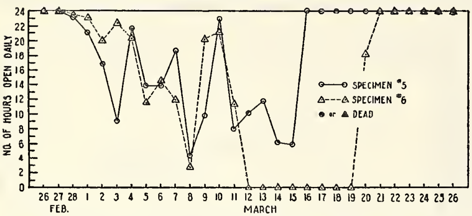

FIGURE 17.—Graph showing the records of the two specimens in experiment No. 20 (2 parts per 1,000). Compare records of controls (fig. 16)

Experiments Nos. 22 and 23 (March 12 to April 11, 1930).—During this series the temperature of the water was 14° to 17° C., except for certain short intervals when the heater was out of order, until April 1 when it was no longer heated and the temperature varied from 8° to 12° C. The pH of the water was 7.7 to 7.9. The stock liquor solution consisted of 1 part pure liquor to 9 parts sea water.

Experiment No. 23 (0.67 parts per thousand.)—Water entered the mixing chamber at the rate of 136 cubic centimeters per minute, and liquor solution (1 : 9) at the rate of 0.9 cubic centimeters per minute. The pH of the solution in the experimental tank varied from 7.1 to 7.5.

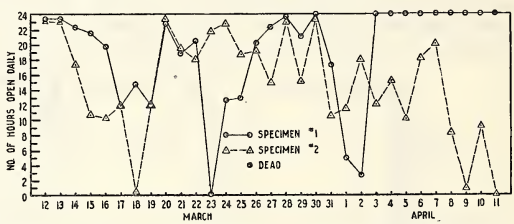

FIGURE 18.—Graph of records of specimens in experiment No. 23 (0.67 part per 1,000). There is considerable fluctuation in the curves, and only one of the specimens died before the test was discontinued. Compare with the records of the control oysters

Both specimens Nos. 1 and 2 (fig. 18) were open about 23 hours per day before liquor was started dripping into the mixing chamber on March 13 at 10.30 a. m. Then both oysters showed marked disturbances. From March 14 until April 2 specimen No. 1 averaged 16.21 hours per day open. From April 3 to 10 the specimen was gaping wide and making infrequent movements, at the end of which time death occurred after 28 days of treatment. Specimen No. 2 did not die during the period of the experiment, but averaged only 14.49 hours per day open from March 14 to April 11, during the 29 days of treatment.

The control specimens behaved in a strikingly different manner. (Fig. 19.) From March 14 until the experiment was stopped (29 days) specimen No. 3 was

open an average of 22.9 hours per day and specimen No. 4 remained open 21.78 hours per day on the average. At the end of the experiment these oysters showed new shell growth and had thrown out considerable quantities of débris, neither of which was true of the experimental specimens save that they left very small amounts of débris.

Experiments No. 22 (1.0 part per thousand).—The rate of water flow was 120 cubic centimeters per minute and that of liquor solution (1 : 9) was 1.2 cubic centimeters per minute. The pH of the solution in the experiment chamber was 6.8 to 7.3.

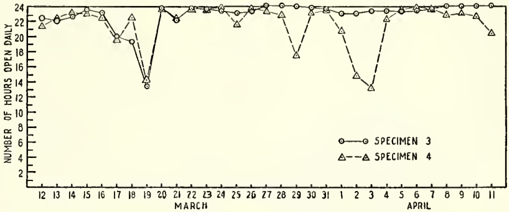

FIGURE 19.—Graph presenting the records of the control specimens of experiments Nos. 22 and 23. Compare with Figures 18 and 20

The results obtained from these two specimens (fig. 20) are very different from one another. Specimen No. 5 remained open an average of 23.66 hours per day from March 14 until the 24th, when it showed marked signs of gaping and cessation of activity. The last movement occurred on the 28th, 15 days after treatment had started. Specimen No. 6, however, remained closed most of the time, averaging only 6.74 hours per day open from March 14 to April 11, when the series ended. This behavior is definitely abnormal, as will be seen by comparing this record with those of the controls. (Fig. 19.)

Experiments Nos. 8 and 9 (December 13, 1929 to January 1, 1930).—Stock liquor for this series consisted of 1 part pure liquor to 9 parts sea water. During only part of the time was the water heated. Because of an apparent change of behavior due to temperature variation a graph (fig. 24) is presented giving average daily temperatures of the water, calculated from hourly thermograph readings. This will be referred to below. The pH of the water was 7.8. One kymograph sheet of the series was unfortunately destroyed.

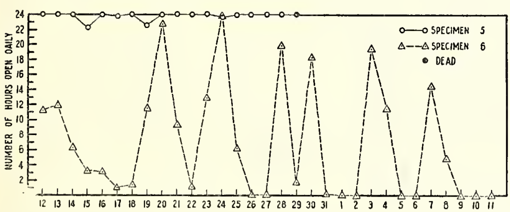

FIGURE 20.—Showing a graph of the records of the two specimens in experiment No. 22 (1 part per 1,000). One specimen remained open most of the time and died, while the other one was still living when the experiment was discontinued. Compare with the controls (fig. 19)

Experiment No. 9 (0.7 part per thousand).—This solution was made by water flowing into the mixing chamber at the rate of 3.48 cubic centimeters per minute, and liquor solution (1 : 9) at 2.5 cubic centimeters per minute. Both specimens reacted normally in pure water before liquor was started on December 14 at 9 p. m. Soon thereafter both began to stay open less hours per day. The graph (fig. 21) shows the behavior up until the experiment was ended. Specimen No. 1 averaged during the

period of treatment 15.82 hours per day open, and specimen No. 2 averaged only 8.11 hours per day open. At the same time, however, the controls (fig. 22) did not remain open as long as expected. While specimen No. 3 averaged 17.42, specimen No. 4 averaged 18.22 hours per day open, during the period in which the expcrimental specimens were in liquor solution. Both controls, however, gave a higher average than either of the experimental oysters. The reason for the confusion appears in Figure 24, in which daily temperatures are presented. The curves of all specimens in both experiments show almost perfect parallel to the temperature fluctuations. They were open more at high than at low temperatures. The effect of temperature on shell movements is discussed more fully in another publication. (Hopkins, 1931.) This explains the low records of the controls, but it does not explain the distinctly lower records made by the experimental oysters, which show that the presence of the liquor caused an additional effect. All specimens were living when the test was ended.

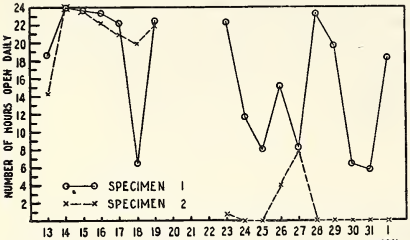

FIGURE 21.—Graph showing records of the two specimens in experiment No. 9 (0.7 part per 1,000). Kymograph sheet covering records for three days were lost. Compare with controls (fig. 22) and with the record of daily temperature, the fluctuations of which caused much of the variability in the behavior of the specimens

Experiment No. 8 (0.44 parts per thousand).—In this case water flowed at the rate of 368 cubic centimeters per minute and liquor (1:9) at 1.6 cubic centimeters per minute. The two specimens (fig. 23) gave inconclusive results during the short experimental period. Specimen No. 5 averaged 19.21 and specimen 6, 13.0 hours per day open. These figures are not different enough from the controls to be significant. For such a low concentration a longer period of treatment appears to be necessary.

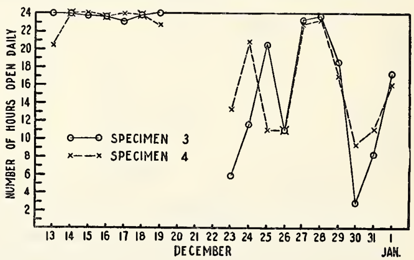

FIGURE 22.—Graph giving records of the control oysters in experiments Nos. 8 and 9 (figs. 21 and 23). The variability in height of records is parallel to fluctuations in water temperature (fig. 24)

Experiments Nos. 2 and 3 (October 20 to November 22, 1929).—These tests were carried on in unheated water of pH, seldom varying from 7.8. The temperature of the water was between 12° and 13° C. at the beginning but by the time the experiments were stopped had fallen to around 5° C. The stock liquor solution was made up of 1 part pure liquor to 19 parts sea water.

Experiment No. 2 (0.52 parts per thousand).—Water entered the mixing chamber at the rate of 84 cubic centimeters per minute and liquor (1:19) at 0.88 cubic centimeters per minute. The pH of the mixture was 7.2 to 7.6 in the experiment chamber.

Effect of the liquor is clearly shown in the graphs (fig. 25) of these two specimens as compared with those of the two controls (fig. 26). After the liquor was introduced

on October 23 and until the end of the experiment, specimen No. 1 averaged 6.76 while specimen No. 2 averaged 7.06 hours per day open. For a comparable period of time (October 22 to November 23) control No. 3 averaged 19.86, while No. 4 averaged 16.44 hours per day open. Even the controls show a more or less progressive lowering of the curves. This was due, as in the case of experiments Nos. 8 and 9, to temperature fluctuation. During the tests the average daily water temperature fell gradually from about 13° C. at the beginning to about 5° C. at the end of the series. This, however, does not interfere with the well warranted conclusion that the presence of the liquor was the cause of the experimental oysters remaining open less, for the controls were open more than twice as much.

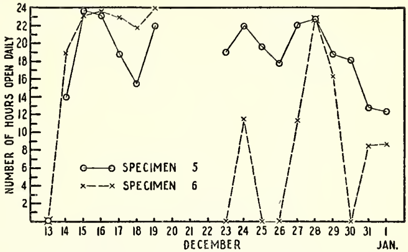

FIGURE 23.—Graph showing records of the two specimens in experiment No. 8 (0.44 part per 1,000). Compare with the controls (fig. 22) and the temperature record (fig. 24)

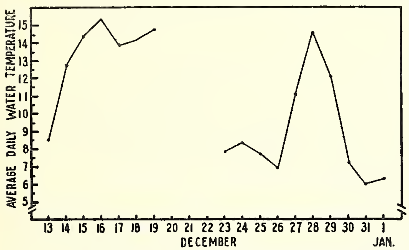

FIGURE 24.—Graph showing average daily temperature of the water in experiments Nos. 8 and 9. At times the water was heated, while during other periods it was cold. These temperature changes are accompanied by changes in the behavior of the oysters (figs. 21 to 23)

Experiment No. 3 (0.83 parts per thousand).—The water rate was 300 cubic centimeters per minute and that of liquor (1:19) was 5.13 cubic centimeters per minute. The pH of the solution varied between 7.0 and 7.5. The results compare favorably with those obtained in experiment No. 2 and show a definite reduction in number of hours per day open. (Fig. 27.) During the experimental period specimen No. 5 averaged 8.51 and specimen 6, 9.49 hours per day open, as compared with controls Nos. 3 and 4, which remained open 16.44 and 19.86 hours per day, respectively. Comparison of the record of specimen No. 5 with the records of other

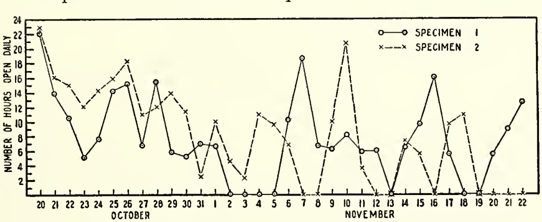

FIGURE 25.—Records of the oysters used in experiment No. 2 (0.5 part per 1,000). As compared with the controls (fig. 26), these specimens remained closed a large proportion of the time

oysters which died under treatment (figs. 8, 10, 11, 13, 15, 17, 18) suggests that this specimen, after having remained closed for a long time, was opening slowly to die.

In order to show the results obtained with all six specimens used in experiments Nos. 2 and 3, Table 1 is appended. The difference between the length of time that

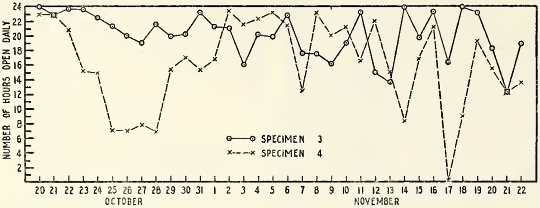

FIGURE 26.—Records of the controls in experiments Nos. 2 and 3 (figs. 25 and 27). The records are not as high as expected, though much higher than those of the experimental specimens. This was due, apparently, to the relative gradual fall in temperature from about 13° C. at the beginning to about 5° C. at the end of the series

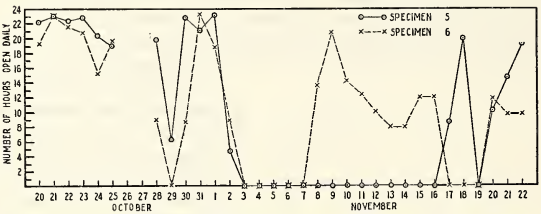

FIGURE 27.—Records of specimens in experiment No. 3 (0.83 part per 1,000). Compare with the controls (fig. 26)

the oysters in the three groups remain open is striking, expecially when the tendency for the treated specimens to remain closed continuously for several days is noted.

TABLE 1.—*Experiments 2 and 3 and controls. Length of time specimens remained open as influenced by the presence of sulphite liquor. Liquor was started on October 23*

Date	Number of hours open					
	Experiment No. 2, 0.5 part liquor per thousand		Controls, sea water		Experiment No. 3, 0.83 part liquor per thousand	
	Specimen No. 1	Specimen No. 2	Specimen No. 3	Specimen No. 4	Specimen No. 5	Specimen No. 6
Oct. 20	21.9	23.0	24.0	23.0	22.3	19.4
21	13.8	16.2	22.9	22.9	23.1	23.2
22	10.5	15.0	23.7	20.8	22.4	21.8
23	5.2	12.1	23.6	15.2	22.9	20.8
24	7.7	14.1	22.5	15.1	20.4	13.3
25	14.1	15.9	21.5	7.0	19.0	19.8
26	15.2	18.3	20.0	7.0	----------	----------
27	6.7	11.0	19.1	7.9	----------	----------
28	15.4	12.1	21.6	7.0	19.8	8.9
29	5.7	13.1	20.0	15.4	6.3	0
30	5.2	11.4	20.3	16.9	22.7	8.7
31	7.0	2.4	23.4	13.5	21.3	23.2
Nov. 1	6.6	10.0	21.4	16.9	23.1	18.8
2	0	4.5	21.0	23.4	4.6	8.9
3	0	2.4	16.1	21.7	0	0
4	0	10.9	20.4	22.3	0	0
5	0	9.8	19.9	23.2	0	0
6	10.2	6.8	22.8	21.4	0	0
7	18.6	0	17.7	12.4	0	0

TABLE 1.—*Experiments 2 and 3 and controls. Length of time specimens remained open as influenced by the presence of sulphite liquor. Liquor was started on October 23*—Continued

Date	Number of hours open					
	Experiment No. 2, 0.5 part liquor per thousand		Controls, sea water		Ecperiment No. 3, 0.83 part liquor per thousand	
	Specimen No 1.	Specimen No. 2	Specimen No. 3	Specimen No. 4	Specimen No. 5	Specimen No. 6
Nov. 8	6.5	0	17.6	23.3	0	13.5
9	6.2	10.2	16.2	19.9	0	20.8
10	8.1	20.5	19.1	21.2	0	14.3
11	5.8	3.6	23.3	16.4	0	12.4
12	5.9	0	15.0	22.1	0	9.9
13	0	0	13.7	14.9	0	8.0
14	6.4	7.3	24.0	8.3	0	7.9
15	9.6	5.6	19.8	16.7	0	12.1
16	16.0	0	23.4	21.3	0	12.1
17	5.5	9.9	16.5	0	8.7	0
18	0	10.7	24.0	9.0	19.8	0
19	0	0	23.3	19.3	0	0
20	5.3	0	18.3	15.4	10.3	11.9
21	8.9	0	12.3	12.3	14.7	9.8
22	12.5	0	19.0	13.5	19.4	9.7
Total, 34 days	260.5	276.6	687.4	546.6	[1] 300.8	[1] 330.2
Average for 31 days of liquor treatment	6.76	7.06	19.86	16.44	8.51	9.49

[1] Total for 32 days only.

EXPERIMENTS WITH NEUTRALIZED LIQUOR

After sulphite liquor has been in sea water for some time the mixture ceases to give an acid reaction, due partially to neutralization by substances in the sea water and partially to loss of sulphur dioxide. It is necessary to be sure that, in the laboratory experiments, the effect of the liquor was not due to acid content.

A series of experiments was arranged to consist of 2 control oysters; 2 in a solution of 10 parts per thousand, and 2 in a solution of 5 parts per thousand of neutralized liquor in sea water. To the digester liquor was added concentrated NaOH solution until the pH of sea water was not changed by addition of the liquor. The liquor was then allowed to set for from 12 to 24 hours to permit the precipitate, probably chiefly calcium sulphate, to settle. Then it was decanted and filtered through several layers of cheesecloth, which removed most, but not all, of the precipitate.

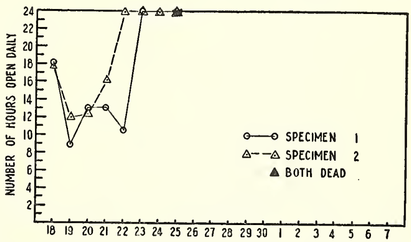

FIGURE 28.—Records of oysters in experiment No. 25 (10 parts per 1,000) in which neutralized sulphite liquor was used. Compare with the controls (fig. 29) which remained open and normally active long after these were dead

Experiments Nos. 24 and 25 (April 18 to May 8, 1930).—Throughout the series, for either concentration employed, the pH of the solution in the experimental tanks did not vary more than 0.2 points from the pH of the control water (7.8). The temperature of the water varied from 10° to 15° C.

Experiment No. 25 (10 parts per thousand).—The rate of flow of water was 103 cubic centimeters per minute and that of liquor solution (1:4) was 5.1 cubic centimeters per minute. Both oysters (fig. 28) were normally open and active when liquor

was started on April 18, at 2.20 p. m., and thereafter both specimens showed marked reactions.

Specimen No. 1, from April 19 to 22, after which it began to gape wide and movements became less frequent, was open an average of only 5.55 hours per day. The last movement occurred on the 24th, after 6 days of treatment. From the 19th until specimen No. 2 began to gape at the end of the 21st, this oyster was open an average of 13.57 hours per day.

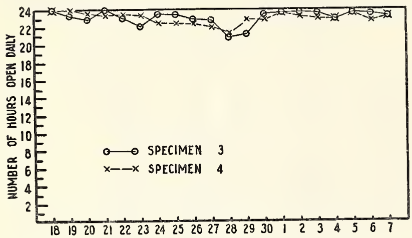

FIGURE 29.—Records of the control specimens in experiments Nos. 24 and 25. Compare with the experimental oysters (figs. 28 and 30)

During the same period of time both controls were open and normally active about 23 hours per day. (Fig.29.)

Experiment No. 24 (5 parts per thousand).—The rate of flow of water was 111 cubic centimeters per minute and that of liquor solution (1:4) was 2.8 cubic centimeters per minute. Both specimens tended to remain closed after the liquor was started. During the time of treatment, from April 19 until it started gaping after May 7, specimen No. 5 (fig. 30) averaged only 4.41 hours per day open. Similarly, specimen No. 6 remained open an average of 5.86 hours per day up until gaping started on May 6. Specimen No. 5 was considered dead after 20 days of treatment and specimen No. 6 after 18 days. Compare these results with the records of the controls. (Fig. 29.)

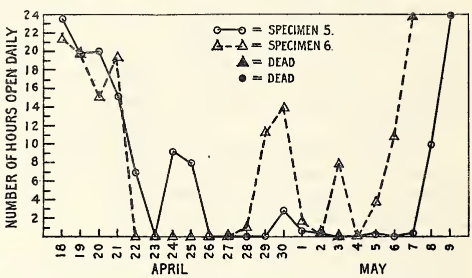

FIGURE 30.—Records of specimens in experiment No. 24 (5 parts per 1,000, neutralized sulphite liquor). Compare with the controls (fig. 29)

From these results, obtained with neutralized liquor, it is clear that it is not the acid content of the liquor which exerts the major unfavorable influence upon oysters. The time required for the specimens to die is easily within that which would be expected from a comparison of the death periods of specimens treated with acid liquor. In Figure 33 and Table 3 it is shown that when the length of time that specimens remain open is taken into consideration the results of these specimens agree substantially with those of other experimental oysters.

In the tests with unneutralized liquor it was noted that the pH of the solutions in the experimental chambers was not highly acid, as compared to the freshly mixed solutions used in the sensory stimulation experiments. This is due partially to the fact that stock liquor was mixed with sea water and during the few days that a bottle of this lasted was slowly partially neutralized. But it is chiefly due to the exposure of the liquor to air in the dripping apparatus. This allowed most of the sulphur dioxide gas to escape, so that the relatively slight acidity of the final solution could hardly be expected to produce any unfavorable results.

SENSORY REACTION TO LIQUOR

Along the edges of the mantle of the oyster are two rows of delicate tentacles which are sensory in function, and presumably serve to test the character of the entering water. When certain chemical solutions are brought into contact with these tentacles they retract sharply; and, if the chemical be sufficiently irritating, the retraction spreads to adjacent portions of the mantle and finally to the entire organ. Following such stimulation the adductor muscle contracts, protecting the oyster by closing the valves.

A method of measuring the sensitivity of the tentacles was devised. It need not be described fully here, but it consisted in measuring the length of time, or latent period, after the solution touches the tentacles, that they retract. These measurements were made over a relatively small temperature range, from 16° to 18° C.

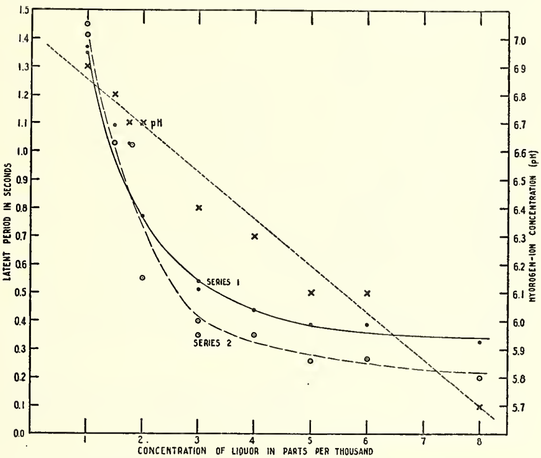

FIGURE 31.—The latent period of the reaction of the tentacles of the oyster to sulphite liquor. Two series are shown, as well as the pH of the solutions. See description in text

Two series of tests with different specimens are presented in Figure 31. Each point represents an average of at least 10 readings. On the same graph the pH values of the liquor solutions are plotted. The sea water in which the specimens were immersed was of pH 7.8.

The resulting latent period curves are typically logarithmic, but need no analysis here. The latent period is extremely short for a concentration of 8 parts per thousand, where the curves appear to be almost horizontal. Between this concentration and the minimum which produced a very sharp reaction (1 part per thousand), the curve increases the angle it makes with the horizontal until it becomes almost vertical. The measurable latent period of the tentacular reaction is limited to concentrations of 1 part per thousand or higher. Control tests with liquor neutralized with NaOH gave the same latent period values, though the reaction was less clearly defined and the error therefore greater.

It is interesting to compare these curves with those presented in the accompanying report by Galtsoff on the influence of liquor on the rate at which the oyster takes

in water. He found that the effect disappears at about 1 part per thousand, and that no water is pumped at about 8 parts per thousand. The latent period curves become approximately straight at these two limits, suggesting that the effect of the liquor noted by Galtsoff is produced directly through sensory or nervous channels.

DISCUSSION OF RESULTS

It is unfortunately impossible to present in a single graph all of the results which have been described in the foregoing account. In the first place the results fall into two groups, depending upon whether the specimens died during the period for which the tests were continued, or whether at this time they were still living but reacting in some other manner to the liquor. Large individual variations in susceptibility make it difficult to express the results mathematically.

In Table 2 the essential points of the results are given to show the difference between the activity of the experimental oysters and that of the controls. The records of the two control specimens of a series are averaged to serve as a basis for comparison with the treated oysters. The percentage of reduction, from the normal or control records, in the number of hours per day that treated specimens remain open is given for each oyster. In these values there is a great variation. This is due, in the first place, to the fact that all experiments were not continued equally long, and also to the marked individual difference in behavior of two specimens in the same solution. In the descriptions of the individual experiments it was pointed out that, when treated with a certain concentration of liquor, one specimen might remain open as much, or almost so, as the controls, and die within a few days, while the other specimen might protect itself by remaining closed a large proportion of the time, with the result that it would live longer. Why this variation should be so great is not clear.

TABLE 2.—*Summary of data on the effect of sulphite liquor on the Olympia oyster, showing death time and percentage of difference in time open between control and experimental specimens*

[In certain cases, designated by (−), the controls were open slightly less than the experimental oysters (see text description)]

Experiment number	Concentration parts per thousand	Specimen number	Death time in days	Hours per day open	Controls average hours per day open, 2 specimens	Difference (in hours per day open) between experimental and control specimens	Per cent difference
1	6.0	3	2	14.3	21.03	6.73	32.0
17	10.0	1	14	7.7	22.85	15.15	66.3
		2	19	2.4		20.45	89.4
16	5.0	5	15	10.4	22.85	12.45	54.5
		6	13	22.5		.35	1.5
24	5.0	5	20	4.41	23.08	18.67	80.4
		6	18	5.86		17.22	74.6
25	10.0	1	6	5.55	23.08	17.53	75.9
		2	6	13.6		9.48	41.1
19	2.4	1	29	14.25	19.28	5.03	26.1
		2	27	16.14		3.14	16.3
18	3.2	5	12	19.6	19.28	−.32	−1.5
		6	21	13.3		5.98	31.0
21	1.3	1	19	17.2	21.0	3.8	18.1
		2	23	1.7		19.3	91.9
20	2.0	5	24	12.93	21.0	9.07	43.2
		6	24	9.9		11.1	52.9
23	.67	1	28	16.21	22.34	6.13	27.4
		2	----------	14.49		7.85	35.1
22	1.0	5	15	23.66	22.34	−1.32	−5.9
		6	----------	6.74		15.60	69.8
13	3.8	1	----------	11.46	23.61	12.15	51.4
		2	----------	18.96		4.65	19.7
12	1.8	5	----------	23.3	23.61	.31	1.3
		6	----------	22.53		1.08	4.6
9	.7	1	----------	15.82	17.82	2.00	11.2
		2	----------	8.11		−9.71	54.4
8	.44	5	----------	19.21	17.82	−1.39	−7.8
		6	----------	13.0		4.82	27.1
2	.5	1	----------	7.06	18.15	11.09	61.1
		2	----------	6.76		11.39	62.8
2	.83	5	----------	8.51	18.15	9.64	53.1
		6	----------	9.49		8.66	47.7

However, in spite of this, certain results stand out sharply. In the first place, many treated specimens actually died in the liquor solutions. Secondly, those specimens which were treated for any considerable length of time with liquor in any concentration employed, from 0.5 to 10.0 parts per thousand, and did not die, were caused to reduce their normal number of hours per day of feeding, as judged on the basis of the activity of the control oysters.

In all, 19 specimens died as a result of the sulphite liquor solutions to which they were subjected. Oysters died after different periods of time in solutions of liquor ranging from 0.67 to 10.0 parts per thousand; that is, 1 part liquor to 1,500 to 1 part to 100.

In Figure 32 a graph is given to show the number of days of treatment after which specimens died in the series of concentrations employed. Although the points on the graph are widely distributed, they appear to fall into a sort of curve of the general form of those presented in Figure 31 for the sensory reaction. There are too few points to allow such an analysis as might permit the prediction of the length of time required for death to occur in even lower concentrations of liquor than those employed. There is a striking difference between the death time of oysters in 10 parts per thousand and that of specimens in about 1 part per thousand. Naturally, as the concentration is lowered the death time increases toward infinity. It is impossible to predict certainly from this whether 0.1 part per thousand, for example, would kill oysters, but it is obvious that, should it do so, it would on the average require considerably over 30 days.

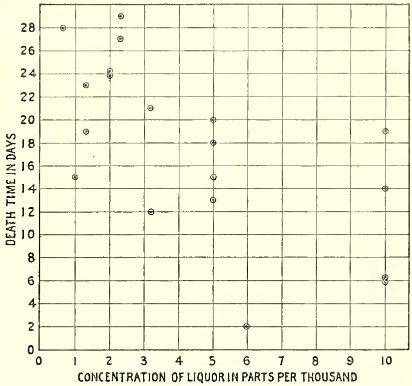

FIGURE 32.—Time required for death in solutions of sulphite liquor in the series of concentrations. The points in general show that the death time increases with diminishing concentration. See Figure 33 and Table 3

Only one specimen died much more quickly than the others, in respect to the concentration used. This was the specimen treated with a solution of 6 parts per thousand which died at the end of two days. The graph (fig. 32) clearly shows, also, that death of all these specimens was due to a particular variable factor in the water. If due to any variable other than the sulphite liquor the points in the graph would be scattered in all directions, regardless of the concentration of liquor used. Further, that the control specimens lived, and grew, and fed well under laboratory conditions demonstrated that these conditions were certainly not unfavorable.

If the death periods of oysters treated with different concentrations of sulphite liquor be plotted in such a manner as to take into consideration the differences in activity of the specimens, a somewhat more complete picture is obtained. In order to do this (fig. 33) the record of each specimen which died was analyzed and the number of hours per day that it remained open computed as percentage of the 24-hour period. The product of this value (average percentage of the time open) multiplied by the number of days required for death, is then considered to represent total effect

of the liquor. (Table 3.) As has been pointed out, the oyster which stays open least during treatment lives longest. Such a composite figure, as stated above, assumes that the fact that an oyster remains closed results in protection. That the assumption is justified will appear on examination of the records of individual oysters. The graph (fig. 33) shows more clearly the decrease in effectiveness of the liquor as the concentration is lowered, and gives a picture of the results not otherwise obtainable. There is, certainly, a fairly wide distribution of the points, but most of them fall into a definite curve.

Table 3.—*Data concerning the specimens which died as a result of treatment with sulphite liquor solutions. These data are shown graphically in Figures 32 and 33*

Experiment number	Specimen number	Death period in days	Average hours per day open	Per cent hours per day open	Mortality factor [1]	Concentration liquor parts per thousand
1	3	2	14.3	60.0	120.0	6.0
17	1	14	7.7	32.1	449.4	10.0
	2	9	24.0	100.0	900.0	10.0
16	5	15	10.4	43.3	649.5	5.0
	6	13	22.5	93.7	1218.1	5.0
19	1	29	14.25	59.4	1722.6	2.4
	2	27	16.14	67.2	1814.4	2.4
18	5	12	19.6	81.6	979.2	3.2
	6	21	13.3	55.4	1163.4	3.2
21	1	19	17.2	71.6	1360.4	1.3
	2	23	1.7	7.1	163.3	1.3
20	5	24	13.0	54.1	1298.4	2.0
	6	24	10.0	41.6	998.4	2.0
23	1	28	16.2	67.5	1890.0	.67
22	5	15	23.6	98.3	1474.5	1.0
25	1	6	5.55	23.1	138.6	10.0
	2	6	13.6	56.6	339.6	10.0
24	5	20	4.41	18.3	366.0	5.0
	6	18	5.86	24.4	439.2	5.0

[1] Mortality factor = death time (days) × per cent of hours per day open.

As stated above, death occurred in some of the specimens in concentrations as low as 0.67 parts per thousand. To this concentration two specimens were subjected (experiment No. 23, fig. 18), but only one died during the time the experiment was continued. The other oyster was still living at the end of the test, but the activity of this specimen could certainly not be called normal. During the entire experimental period this oyster averaged only 14.5 hours per day open, while the two control specimens averaged 22.9 and 21.8 hours per day open, respectively. This experimental oyster was open 35 per cent less time than the controls. Then this oyster was under a disadvantage in that it could take in no more than 65 per cent as much food as normal oysters. This would be the case even if the liquor exerts no direct lethal, or toxic, effect upon the oyster in other respects. In experiment No. 22 one specimen died while one continued to live during 29 days of treatment with 1 part per thousand. However, the latter, during that period, remained open only 6.74 hours per day on the average. It was able to feed a maximum of only 30 per cent as much as the control oysters.

In experiment No. 2 (0.5 part per thousand) neither specimen died during the 31 days that the test was continued, but both together averaged only 6.9 hours per day open, as contrasted with the controls, which remained open an average of 18.15 hours per day. Feeding time of the experimental oysters was thereby reduced by about 62 per cent.

Experiment No. 3 (0.83 part per thousand) is similar in that the two specimens averaged only 9 hours per day open, a reduction from the records of the control oysters of about 50 per cent.

Table 1 summarizes such data. All specimens which were given a fair test in any concentration, from 0.5 to 10 parts per thousand reacted very unfavorably either by dying or by remaining closed a large part of the time. Lower concentrations were not studied. Sulphite liquor, then, in these concentrations, appears to be definitely harmful to oysters.

These effects are clearly not due to the acid content of the liquor, for the four specimens treated with neutralized liquor died after periods of time entirely comparable to those of specimens treated with acid liquor.

At the beginning of this report attention was called to the fact that in Oakland Bay the oysters showed three peculiarities to an abnormal degree, namely, high mortality rate, poor meats, and lack of growth. Either directly or indirectly these conditions have been reproduced in the laboratory by subjecting normal oysters to various concentrations of sulphite liquor. The death of oysters as a result of the presence of the liquor in concentrations above 0.67 part per thousand has just been described.

It was also stated that concentrations as low as 0.5 part per thousand caused specimens to remain closed more than the presumably normal control oysters. Any factor which causes oysters to remain closed abnormally at the same time deprives them of their due amount of food, for food-bearing water can not enter with the valves closed.

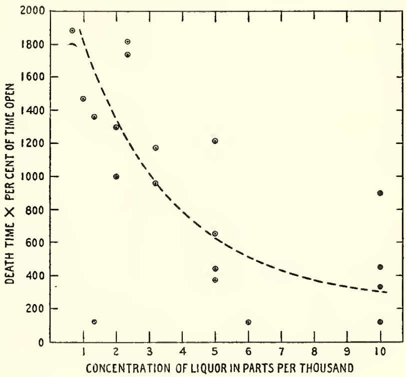

FIGURE 33.—Showing the data given in Figure 32 calculated to include the influence of the proportion of time the shells were open. The points represent death time in days × the percentage of time the valves were open. Since death occurs more quickly when the specimens remain open than when they stay closed, the values calculated as above show more clearly than Figure 32 the inverse relationship between concentration and death time, although individual variations are large

The result would be that specimens subjected to liquor in such concentrations as above stated would be unable to take in as much food as normal oysters, and would consequently be expected to be relatively thin and watery. The results of Galtsoff, in his accompanying report, should be consulted in this connection, for he showed that an open oyster, in certain concentrations of liquor, does not take in water, and food with it, as rapidly as normal specimens.

In the experiments in which water of a temperature around 15° C. was used, the control specimens within two to four weeks developed 1 to 3 millimeters of new, delicate shell growth. Oysters were brought in winter to the laboratory from the cold water in the dikes, where growth could not go on because of the low temperature, so there was no possibility of mistaking the new shell for some already existing. The control specimens, however, were the only ones which grew new shell. In no case was new shell growth observed on an experimental oyster. One reason for this is that when the oysters are in liquor solution, the very sensitive edge of the mantle, which secretes

the new shell, does not extend outward as in the normal oyster, but withdraws several millimeters back into the shell. In addition, there may be more fundamental physiological reasons why treated specimens do not grow, but the above observation has been repeatedly made during these tests.

In an early part of this report it was pointed out that most of the works dealing with sulphite pollution have been concerned with the effect of diminished oxygen supply on fishes. It is certain that sulphite liquor is a strong reducing agent. Some fishes are very sensitive to reduced oxygen content of the water, and it may well be that this constitutes the major harmful effect on them of the liquor. In the case of oysters, however, dissolved oxygen is of secondary importance in this matter, for it is well known that the oxygen requirement of oysters is low. Because of this fact, oysters can be kept out of water for long periods of time with little harmful effect.

Verrill (1885) observed that oysters which were out of water lived for about eight weeks, during which time they necessarily remained closed, or the inclosed water would have been lost. Mitchell (1912) found that medium-sized oysters at between 19° and 28° C. used from 7 to 35 decimilligrams of oxygen per 100 grams of total weight, the amount used varying with temperature. He determined that completely closed oysters take in no more oxygen from the medium than do the shells alone. In one case an oyster lived in an almost oxygen free medium for 7 days without apparent ill effect, although it had absorbed only 1.2 milligrams of oxygen during the period.

Nozawa (1929) showed that the oxygen consumption of the oyster is independent of the oxygen tension until reduced to 0.1 per cent or lower. Even after oxygen consumption is reduced to none, carbon dioxide is still produced, and he agreed with Barkeley (1923) that the crystalline style plays a rôle in this anaerobic respiration. A more complete review of the physiology of respiration in the oyster may be found in the recent publication of Galtsoff and Whipple (1930), who found that oxygen consumption depends upon oxygen tension only when the amount of oxygen in the medium is below 2.5 cubic centimeters per liter.

TABLE 4.—*Showing lengths of time specimens remained closed continuously*

[Only periods of four days or more are included]

Experiment number	Specimen number	Number days closed consecutively	Condition following period of closure
2	1	4	Still living 18 days later.
2	1	6	Still living.
3	5	14	Still living 6 days later.
3	6	6	Still living 15 days later.
16	5	4	Died 1 day later.
17	1	8	Died 6 days later.
18 and 19	4	5	Still living 4 days later.
20	6	8	Died 5 days later.
21	2	−9	On the 1st, 2d, and 7th days the specimen was open 0.1 hour each. Died 11 days later.
24	5	4	Died 8 days later.
24	6	6	Died 10 days later.

When the valves of the oyster are closed, the normal flow of water is stopped, and very little, if any, oxygen is able to enter. In the experiments just described, it frequently occurred that specimens would remain closed for many consecutive days without once opening the valves to take in new water. Table 4 summarizes the most important examples of this reaction. Only periods of closure of more than

three days are recorded here, for the purpose of the table is to demonstrate that oysters can remain closed for many days and then still live for a considerable time. These oysters were in solutions of sulphite liquor in sea water. The control specimens in pure sea water remained open an average of more than 20 hours per day, and in no case did one of them die as a result of the tests.

One oyster (experiment No. 3, specimen No. 5) remained constantly closed for 14 days, after which it opened and lived for at least 6 more days. Others stayed closed for shorter periods of time without damage as due apparently to this cause. It has already been pointed out that specimens in liquor solutions live longer the greater portion of the time they remain closed. If death were due to lack of oxygen, this would not be expected. When such a specimen closes after having been in the liquor solution for some time, the fluid filling the mantle and gill chambers is the same as that in the experimental tank. The liquor would slowly use up all of the available oxygen in this inclosed water, and it would be expected, therefore, that the oysters which remain closed most would die most quickly, if death is due to lack of oxygen. Such, however, is not the case. In spite of the fact that newly pumped sea water was constantly flowing into the experimental chamber, carrying with it dissolved oxygen, the oysters which remained open and in contact with the new water died more quickly than those which closed. (See fig. 33.)

Oxygen determinations were not made, but instead of this the experiments were so arranged that a large supply of fresh sea water was constantly entering the experimental tanks. The lowest rate of flow of water was 61 cubic centimeters per minute (experiment No. 13) and the highest, 368 cubic centimeters per minute (experiment No. 8). In nearly all cases water entered the experimental tank at well over 100 cubic centimeters per minute. The capacity of each tank was about 3,000 cubic centimeters, so there was ample exchange. When solutions concentrated enough to show a marked color were used, it was observed that within less than one hour after stopping inflow of liquor into the mixing chamber, the color disappeared completely from the solution in the experimental tank.

As explained above, if the harmful effect of the liquor were due to lack of dissolved oxygen, it would not be expected that there would be such a difference in the duration of life of specimens which remained open most of the time and those which stayed closed more. Figure 33 indicates the correlation between time required to kill and concentration of liquor when this factor of shell behavior is taken into consideration. The effect of the liquor appears to be the consequence of mass action. It is progressive and steady when the oysters are open, and the liquor is constantly in contact with the tissues; but that portion of the toxic agent which is inclosed when the oyster closes may soon become exhausted and the tissue is then immersed in a relatively nontoxic medium.

The nature of the toxicity is not known and would be difficult to establish. The work of Galtsoff (accompanying report) demonstrates that the liquor has an immediate harmful effect on the activity of the gill mechanism. This effect, however, appears to be marked only in the relatively high concentrations. As contrasted to the immediate reaction of the ciliary mechanism, the oyster as a whole slowly succumbs as if by progressive poisoning.

The normal oyster under favorable conditions remains open most of the time, the shells closing and opening again periodically. The frequency of these closures is highly variable and the periodicity complicated. While it is difficult to express this activity mathematically, a simple comparison of the normal and experimental speci-

mens in this respect will suffice to show the progressive departure of the sulphite-treated oysters from the normal. Nozawa (1929) said that while the periodic closures of the shells occur in the normal Japanese oyster at about six per hour, after reduction of dissolved oxygen to 2 to 3 cubic centimeters per liter the frequency of shell movements is much reduced, as the time required for opening and closing becomes longer.

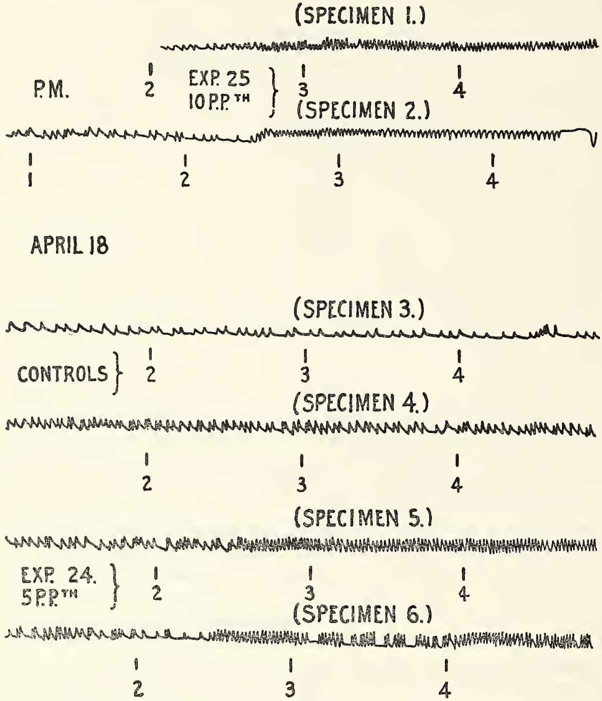

FIGURE 34.—Reproduction of portion of kymograph sheet showing records of shell movements of oysters used in experiments Nos. 24 (5 parts per 1,000; specimens Nos. 5 and 6 at bottom) and 25 (10 parts per 1,000; specimens Nos. 1 and 2 at top). The middle two records were made by the controls (specimens Nos. 3 and 4). Intervals of one hour are indicated. At 2.20 p. m. the liquor solution was started running into the experimental chambers. Note the more frequent shell movements of specimens Nos. 1, 2, 5, and 6 immediately thereafter. See Figures 35 to 38

The primary effect of sulphite liquor solution on the oyster is just the reverse. It stimulates the oyster to close and open more frequently, except shortly before the specimen finally dies. In order to show the typical changes in shell activity from beginning of an experiment until death of the oysters, several reproductions are given of portions of the kymograph records obtained in experiments Nos. 24 and 25. (Figs. 34 to 38.) Figure 34 shows the reactions during the time when liquor was started. There is a distinct change of activity which consists in increased frequency of closures.

The difference between the control and the experimental oysters is very clear, although all specimens are quite active, as is typical of oysters which are immersed after being in air for some time.

Soon another type of shell reaction begins, namely, the tendency to close and remain closed for increasingly long periods. In Figure 35, a few hours farther advanced than Figure 34, this tendency is shown. However, the initial effect, very

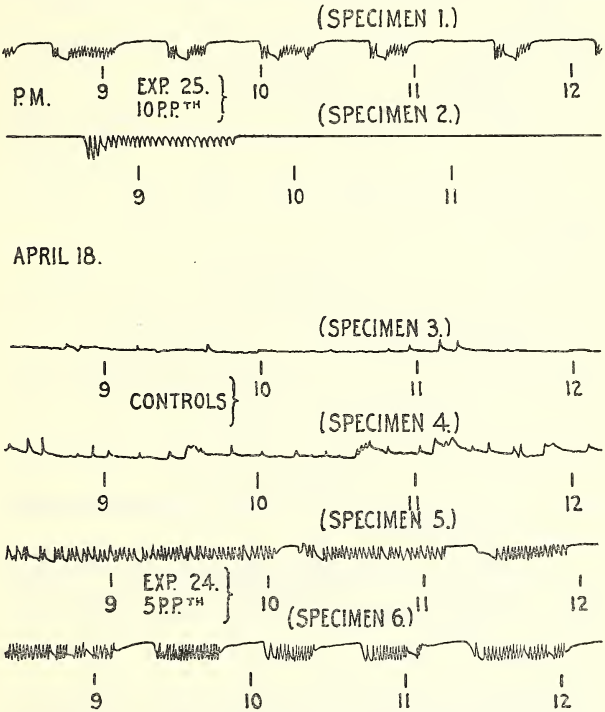

FIGURE 35.—Reproduction of portion of kymograph sheet showing records of specimens used in experiments Nos. 24 and 25, a few hours later than that shown in Figure 34. The tendency to remain closed (high straight lines) and the rapid movements when open are well shown

frequent closures, is still to be observed during the periods of activity or "openness." This continues for some time, depending upon the concentration of liquor and the consequent rapidity with which the toxic action occurs. Then (fig. 36) the periods of remaining closed become shorter and the reactions while open less frequent. At the same time the adductor muscle slowly loses its power to close the shells completely. In the figure this is more obvious in the second record than in the first. That the closure is incomplete after the short opening period is shown by the lower

level of the record as compared with that before opening. Such a specimen is beginning to gape, the adductor muscle losing its tonus, so that the shells open wider than normally. The muscle also loses ability to make a complete contraction. There follows then a period during which gaping becomes more and more pronounced,

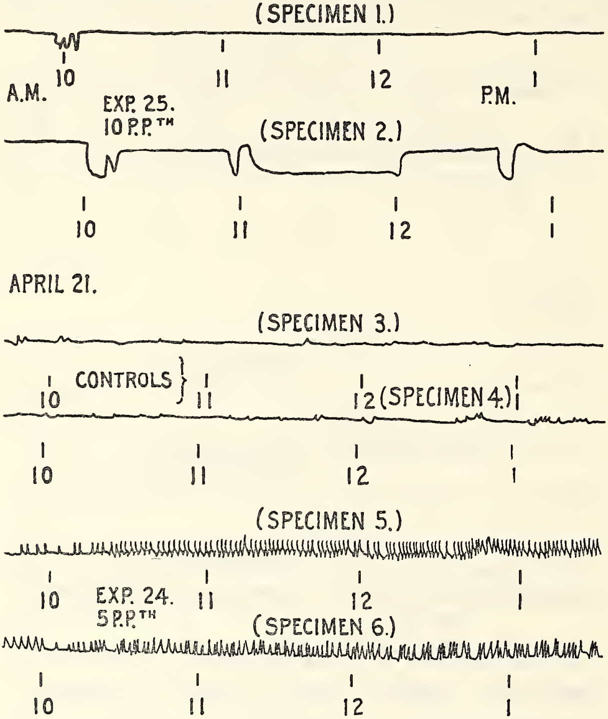

FIGURE 36.—Reproduction of portion of kymograph record of experiments Nos. 24 and 25 about two and one-half days later than that shown in Figure 35. The inability of specimens Nos. 1 and 2 to close completely is shown. The record of specimen No. 1 is wavering, showing that closure was incomplete. The record of specimen No. 2 shows the differences in height of the lines, or differences in degree of closure. Specimens Nos. 5 and 6 in a weaker concentration of liquor are still more active than the controls

complete closure never occurring, and even the partial closures become less frequent. (Fig. 37.)

As the oyster gapes, the constantly less frequent shell movements are also of less amplitude. It will be observed in Figure 37 that the contractions are very weak, but that the muscle acts as if attempting to hold the shells together, instead of relaxing immediately after a contraction, as is typical of the control records. When the oysters are in this condition they are almost at the death point. The last figure of

the series (fig. 38) shows the two records of the experimental oysters as straight lines. All movement has ceased and they are gaping wide open, motionless.

In the experiment just described, the different phases of the oyster's death process followed upon one another within a few days. In tests in which lower concentrations of sulphite liquor were employed, much longer periods of exposure were required before the specimens died. (Bottom two records, figs. 34 to 38.) However, the same

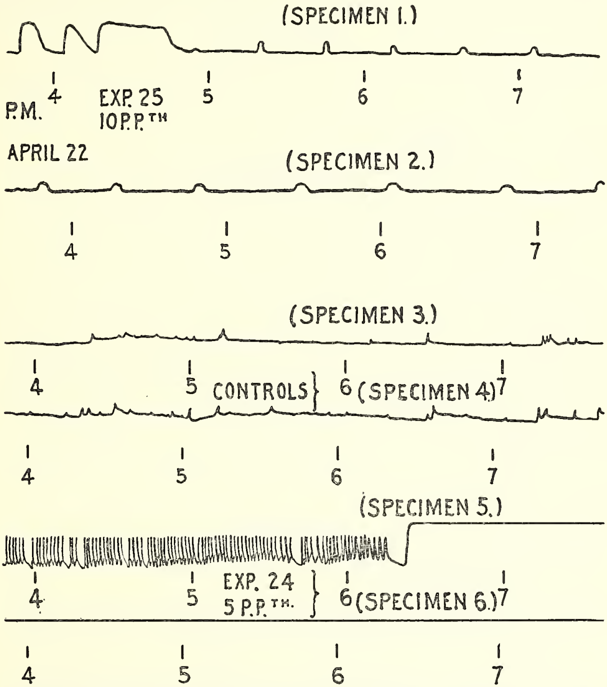

FIGURE 37.—Reproduction of portion of kymograph record of experiments Nos. 24 and 25, one day later than that shown in Figure 36. Specimens Nos. 1 and 2 have lost their ability to close completely and movements are relatively slight and infrequent. Specimens Nos. 5 and 6, in weaker concentration of liquor remain closed a large part of the time, and when open are very active. The behavior of these is similar to that of specimens Nos. 1 and 2 about three days previously, as shown in Figure 35

sequence of the different phases of the activity of the oysters during treatment was observed to hold, although each phase was very much prolonged.

The most striking characteristics of the reactions before the approach of gaping were the tendency to remain closed for long periods and, while open, to make abnormally frequent temporary closures. If there had been a marked deficiency of oxygen, the specimens would have become less active from the beginning, according to the

observations of Nozawa (1929). The reaction which he described was observed to occur, as described above, as one of the late stages just preceding gaping. This diminished activity is probably typical of an oyster dying from any cause.

It would be of considerable importance to determine what components of the sulphite liquor are the actual toxic agents. It may well be that some substance is contained in the liquor in such small quantities as to pass unnoticed in ordinary chemical analyses, but which exerts a toxic effect upon the oyster. Such a substance

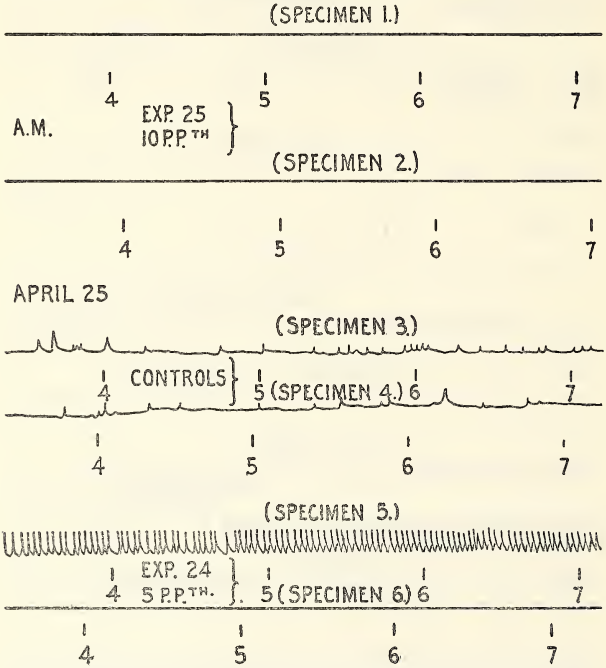

FIGURE 38.—Reproduction of portion of kymograph record of experiments Nos. 24 and 25, about two and one-half days later than that shown in Figure 37. Specimens Nos. 1 and 2 are dead and the shells are gaping open without movement. Specimen No. 5 is open and highly active while specimen No. 6 is closed. The controls (3 and 4) show normal activity

might be extremely dilute and yet toxic. To some substances aquatic animals may be highly sensitive. Marsh (1908) found, for example, that silver nitrate killed salmon fingerlings in 24 hours at a dilution of 1 to 22½ million. The toxicity of this substance as compared with that of sulphite liquor is tremendous.

That the acid content of the liquor was not responsible for the harmful effect was shown by the fact that oysters died in neutralized solutions, as described above, as well as by the observations of Galtsoff, as reported in an accompanying paper, that

neutralized liquor produced a diminished feeding rate. Further, the oxygen requirement of the liquor, while it might be of significance if experiments were carried on in stagnant water, is not the important factor. Both in the above described experiments, in which running, newly pumped water was continuously provided, and in the experiments of Galtsoff, in which the solution was constantly stirred and aerated, the possibility of insufficient dissolved oxygen was eliminated.

Acidity and oxygen demand have generally been considered to be the cause of the harmful effect of sulphite pollution. While this may be the case to a great extent in fresh-water streams, it is of little significance from the point of view of pollution of waters near oyster grounds. The customary recommendations that liquor be neutralized and exposed to air in ponds before allowing it to enter bodies of water may not be made with any confidence where the body of water concerned contains oyster beds. Until all toxicity is removed from such wastes, if such is possible, they should be completely excluded from waters where oysters are grown.

In order to work out all of the problems connected with removal of toxicity from the liquor, a great amount of research would be required. It would be of importance to determine whether the toxicity is slowly destroyed in sea water. It might possibly be expected that oxidation would slowly eliminate such substances. However, in this case there is no reason for assuming that this would occur, since the actual toxic agents are unknown. The results of the present work as correlated with those of McMillin and Galtsoff, in accompanying reports, rather indicate that destruction of the toxicity of the liquor in Oakland Bay has not progressed very rapidly.

McMillin was able to calculate, with reasonable accuracy, the maximum concentration of liquor which would develop in Oakland Bay following regular dumping of known quantities by the mill. He found that when an average of about 70,000 gallons of liquor is dumped daily, the equilibrium developed in the bay would be stronger than 1 part per thousand, and that in the neighborhood of a year would be required to reach this equilibrium. These calculations assume that no destruction of the toxic agents takes place. In the laboratory experiments described above, it was shown that liquor in concentrations of 1 part per thousand or above kill oysters within less than a month. Lower concentrations produce death after a longer period of time. There appears to be a clear relationship between the time required to kill and the concentration of liquor. Oysters died in concentrations as low as 0.67 part per thousand.

While the oysters in the laboratory were constantly subjected to the same concentration, this would be true of the oysters in the bay only if complete mixing took place. However, complete mixing and distribution of the liquor throughout the bay would be a slow process. Further, at low tide the oysters are subjected to the relatively pure seepage water, which would allow for some recovery. In Oakland Bay oysters were first observed to be dying about a year after the mill started operations, which is about the same time as McMillin calculated would be necessary for development of equilibrium if complete mixing and distribution should take place at a rapid rate.

The close correlation, therefore, between the time of theoretical building up of the equilibrium concentration, the beginning of mortality of oysters in the bay, and the results of laboratory experiments on the effect of different concentrations, appears to indicate that toxic substances in the liquor were at least partly responsible for the abnormal mortality of oysters in Oakland Bay. This agreement between the results of the several phases of these investigations is of the utmost importance, for on the

basis of these principles it would be theoretically possible to predict the effect of sulphite liquor on oysters in any other body of water on which a similar mill might locate.

Since sulphite liquor is poisonous to oysters, either killing them or causing them to take in less food, it should be totally excluded from tidal areas in which oysters are cultured. There is a fundamental difference between the results of dumping wastes into a flowing stream on the one hand, and into a tide-controlled bay or estuary, on the other. In the former case, the waste matter is diluted and washed away by constantly flowing, unpolluted water. In the latter case the liquor becomes mixed with water the movement of which, for the most part, consists in back and forth fluctuations. The same water, with relatively minor variations, remains day after day. To what extent this would be true depends upon the degree to which the body of water in question is inclosed and its total volume, the amount of fresh water entering, the difference between the tides, and the consequent actual loss of water. Other factors, such as direction and rate of currents with respect to location of oyster grounds and source of pollution, would have to be given consideration.

The extent of the damage to oysters in any such location might be predicted if the equilibrium concentration calculated should be as high as the concentrations studied in the laboratory. For lower theoretical equilibrium concentrations, however, low they might be, it would never be safe to say that no damage would be done, for all of the effects observed in the laboratory occurred within the relatively short time of one month. The dilution at which toxicity ceases, when long periods of exposure are considered, can not be stated. Only complete exclusion of liquor from oyster-producing waters can be considered as safe.

SUMMARY AND CONCLUSIONS

(1) Sulphite liquor, when added to sea water in concentrations from 0.5 to 10.0 parts per thousand, is decidedly unfavorable to oysters (*Ostrea lurida*).

(2) In concentrations from 0.67 to 10.0 parts per thousand most of the specimens died after being treated for from 2 to 29 days, depending upon the concentration of liquor.

(3) In all concentrations tested (0.5 to 10.0 parts per thousand) for a reasonably long period of time the specimens either died, or they remained closed much longer daily on the average than did control specimens in presumably uncontaminated water.

(4) When the temperature of the water in the laboratory was sufficiently high, in the vicinity of 15° C., the control specimens showed 1 to 3 millimeters of new shell growth within 2 to 4 weeks. Specimens in water containing liquor did not show any perceptible growth. The mantles of treated oysters remained withdrawn into the shell instead of protruding slightly at the edge of the shell where new shell is secreted.

(5) The effect of sulphite liquor on oysters is not due to acidity, for its potency is not disturbed by neutralization with NaOH.

(6) The chief characteristics of the abnormal oysters in Oakland Bay (namely, high mortality rate, poor meats, and lack of shell growth) have been produced either directly or indirectly in the laboratory by adding various amounts of sulphite liquor to the water.

(7) Concentrations of from 0.5 to 10.0 parts per thousand only were adequately tested in the laboratory, but it is not to be assumed, therefore, that in less concentrated solutions the liquor is harmless to oysters. The solutions tested required only about 35 days, at most, to produce the effects described in this report, and higher

dilutions might well be expected to produce an unfavorable effect after a longer period of time.

(8) From the calculations of McMillin in an accompanying report it is seen that the concentration of liquor which would be expected in Oakland Bay is within the limits of the concentrations tested in the laboratory. At such concentrations the liquor is definitely harmful.

(9) It is recommended that pulp mills using the sulphite process totally exclude waste liquor from waters in which oysters are grown. It is not impossible to dispose of waste liquor by means of by-products plants or by evaporating and burning, and such measures should be employed in the interest of such natural resources as oysters.

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II. THE EFFECT OF SULPHITE WASTE LIQUOR ON THE RATE OF FEEDING OF *OSTREA LURIDA* AND *OSTREA GIGAS*

BY PAUL S. GALTSOFF

The mode of feeding of oysters and other lamellibranch mollusks consists in producing a strong current of water which passes through the gills and in catching, conveying toward the mouth, and ingesting the suspended particles which were brought in with the stream of water. The maintenance of a steady current is dependent on the ciliary motion of the lateral cilia which, by beating inward, that is, at a right angle to the surface of the gill, produce the necessary pressure inside the gill cavity. It has been shown in previous investigations of the author that two factors, the rhythm of the ciliary beats and the coordination of the ciliary activity throughout the whole layer of ciliated epithelium, control the rate of flow of water through the gills. Both of these factors can be affected by physical and chemical changes in the surrounding medium. Some of them (as for instance, mechanical stimulation) may have no direct influence on the rate of beating of the cilia, yet they may produce a pronounced effect on the coordination of ciliary motion and result in a loss of head pressure in the gills and a subsequent sharp decrease in the rate of flow. Changes in chemical composition of the sea water may affect both factors simultaneously and cause disturbances in the operation of the ciliated mech anism. One would expect, therefore, that the discharge into the sea of large quantities of any waste product, even nontoxic, would upset the chemical equilibrium in the solution of salts in the sea water and would interfere with the normal activity of the organisms growing in it. A study of the effect of pulp mill wastes on the activity of the ciliated epithelium of the oyster presented, therefore, a problem which was both interesting from a scientific point of view and important because of its practical application.

This study was carried out in October, 1929, at the Jaques Loeb Laboratory at the Hopkins Marine Station, Pacific Grove, Calif. Oysters for experimental work were received from Olympia (*Ostrea lurida*) and from Samish Bay (*O. gigas*, the Japanese oyster). Olympia oysters, shipped by boat from Olympia to San Francisco and by train from San Francisco to Pacific Grove, arrived on the fifth day; Japanese oysters were expressed and were en route four days. In both cases the oysters arrived in good condition and apparently did not suffer from transportation. They were placed in large tanks with running sea water where they were kept for four weeks. There was no indication of unusual mortality among the oysters. The temperature of the water in the tanks (recorded three times a day) fluctuated from 15° to 17.5° C.; its salinity (daily observations) varied from 33.40 to 33.84 parts per thousand.

The method employed in the present investigation consisted in measuring the velocity of the current of water in the circular glass tubing introduced into the gill cavity. Since this method was fully discussed in previous papers by the author (Science, 1926, Vol. LXIII, pp. 233–234; Journal of General Physiology, 1928, Vol. XI, pp. 415–431; Bulletin of the Bureau of Fisheries, 1928, Vol. XLIV, pp. 1–39) a description of it here is omitted. Because of the small size of the Olympia oyster, the glass tubing used in the experiments with this species was of smaller diameter than the tubing used in the experiments with Japanese and Eastern oysters. During the experiments, oysters were kept in enamel trays containing 5 liters (Olympia oyster) and 10 liters (Japanese oyster) of water. The water was continuously stirred and aerated. No attempts were made to keep the temperature constant; it fluctuated within 2° C. "Red liquor" was received from the Shelton pulp mill; its specific gravity at 15.6° C. was 1.046. Various amounts of red liquor were added to the water in which the oysters were kept, and the rate of flow of water was measured after the oysters were allowed to remain for at least 15 minutes in a given concentration. Each experiment lasted several hours, depending on the number of observations. The values of the rate of flow given in figures are the means of 10 or 20 measurements. The limits of fluctuation are shown in the tables. Numerous controls show that under the conditions of the experiments, the rate of flow through the gills of an oyster, which was kept in pure sea water for several hours remained constant. Thus the decrease in the rate of flow of water observed during the present investigation can be attributed to the effect of the red liquor.

The results of the experiments are shown in Tables 5–7 and in Figures 39–41.

For computing the rate of flow in cubic centimeters per hour, the following formula was used:

$$V = 450\pi D^2 S$$

where D is the diameter of the glass tubing in centimeters and S is the velocity of current at the axis in cms/sec. In the case of *Ostrea lurida*, the diameter of the glass tubing D was 0.33 centimeter; in the case of the Japanese oyster, D equaled 0.68 centimeter.

An examination of the results of the experiments (Tables 5 and 6, figs. 39 and 40) shows that the addition of 2 parts per thousand of red liquor causes a decrease in the rate of flow of water through the gills. At the concentration of 6 parts per thousand, the flow of water in *Ostrea lurida* is about one-fifth of its normal rate; at 9 parts per thousand, it constitutes only 7.3 per cent of the normal rate of a given specimen. It is interesting to note that, beginning with the concentration of 4 parts per thousand, the current becomes less regular, the irregularity increasing with the increase in concentration.

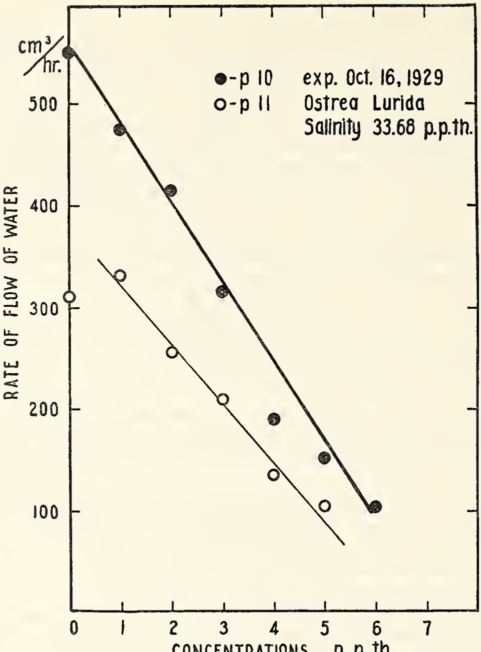

FIGURE 39.—Effect of sulphite liquor on the rate of feeding of *Ostrea lurida*. Temperature, 16.8–17.5° C.; pH, 7.9–6.2

TABLE 5.—*Effect of red liquor (specific gravity 1.046) on the rate of feeding of Ostrea lurida (oyster P–10 is 4.8×3.3 centimeters; P–11 is 3.7×3.4 centimeters). Salinity—33.68 parts per thousand*

[October 16, 1929, Pacific Grove, Calif.]

Time	Temperature	Concentration parts per thousand	pH	Rate of flow, cubic centimeters per hour: Average	Maximum	Minimum	Remarks
P–10	°C.						
2.20 p. m.	16.8	0	7.9	550	573	459	
2.37 p. m.	16.8	1	7.4	474	521	459	
3.10 p. m.	17.0	2	7.0	413	418	370	
3.40 p. m.	17.6	3	6.7	312	336	286	
4.03 p. m.	17.5	4	6.6	199	261	99	Irregular current.
4.27 p. m.	17.8	5	6.3	153	230	115	Do.
5.15 p. m.	17.5	6	6.2	107	143	84	Do.
P–11							
2.25 p. m.	16.8	0	7.9	306	327	286	
2.40 p. m.	16.8	1	7.4	310	318	277	
3.15 p. m.	17.0	2	7.0	230	243	208	
3.45 p. m.	17.6	3	6.7	214	220	144	
4.08 p. m.	17.5	4	6.6	138	167	110	Irregular current.
4.31 p. m.	17.8	5	6.3	107	153	90	Do.
5.20 p. m.	17.5	6	6.2	118	121	115	Do.

TABLE 6.—*Effect of neutral red liquor (specific gravity 1.046) on the rate of feeding of Ostrea lurida (size: 4.2×3.2 centimeters). Salinity of water, 33.64 parts per thousand*

[October 18, 1929, Pacific Grove, Calif.]

Time	Temperature	Concentration parts per thousand	pH	Rate of flow, cubic centimeters per hour			Remarks
				Average	Maximum	Minimum	
P-13	° C.						
11.40 a. m.	16.0	0	8.0	398	428	367	
12.08 p. m.	16.2	.5	8.0	398	408	367	
12.35 p. m.	16.8	1.0	7.9	402	410	395	
12.58 p. m.	16.8	2.0	8.0	367	424	318	
1.20 p. m.	17.0	3.0	7.9	260	301	239	
1.42 p. m.	17.6	4.0	8.0	260	327	230	
2.07 p. m.	17.8	5.0	7.9	184	239	135	
2.46 p. m.	18.0	6.0	8.0	138	230	121	
3.30 p. m.	18.5	7.0	7.9	92	176	60	Current irregular.
4.00 p. m.	17.8	9.0	7.9	30	----------	----------	Current very slow and irregular.
4.00 p. m.	(1)	(1)	(1)	(1)	(1)	(1)	
Oct. 19, 10.25 a. m.	17.8	0	8.0	337	347	327	

[1] Oyster placed in running sea water.

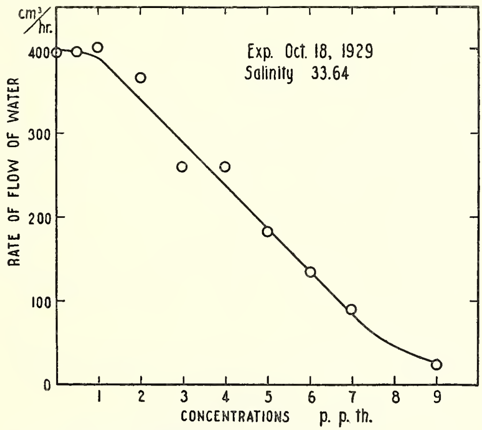

FIGURE 40.—Effect of neutral sulphite liquor on the rate of feeding of *Ostrea lurida*. Temperature, 16.0–17.8° C.; pH, 7.9–8.0

The rate of feeding of the Japanese oyster (Table 7, fig. 41) is also affected by the addition of red liquor, the decrease being noticeable at the concentration of two parts per thousand. The rate of flow continues to fall with the increase in amount of red liquor added. There is, however, a distinct difference between the two species of oysters: The Japanese oyster can sustain higher concentrations much better than can the small Olympia oyster. At the concentration of 15 parts per thousand, the rate of feeding of the Japanese oyster is still about 25 per cent of its normal rate.

TABLE 7.—*Effect of red liquor (specific gravity 1.046) on the rate of feeding of Ostrea gigas (size, 11.3×6.2 centimeters). Salinity, 33.68 parts per thousand*

[October 16, 1929, Pacific Grove, Calif.]

Time	Temperature	Concentration parts per thousand	pH	Rate of flow, cubic centimeters per hour: Average	Maximum	Minimum	Remarks
	° C.						
10.37 a. m.	15.8	0	7.9	3,240	3,240	3,220	
11.07 a. m.	16.0	.2	7.9	3,026	3,356	2,430	
11.40 a. m.	16.4	.4	7.9	3,143	3,356	3,130	
12.11 p. m.	16.8	1.0	7.3	3,156	3,356	3,130	
12.35 p. m.	17.0	2.0	7.0	2,223	2,365	1,944	
12.55 p. m.	17.0	3.0	6.8	1,730	2,112	1,470	Current irregular.
2.48 p. m.	17.4	4.0	6.7	2,028	2,365	1,944	Do.
3.07 p. m.	17.4	5.0	6.4	1,251	1,944	972	Do.
3.35 p. m.	17.6	8.0	6.0	771	1,276	583	Do.
3.52 p. m.	17.5	10.0	5.8	1,244	1,386	972	Do.
4.12 p. m.	17.5	15.0	5.7	816	1,076	609	Do.

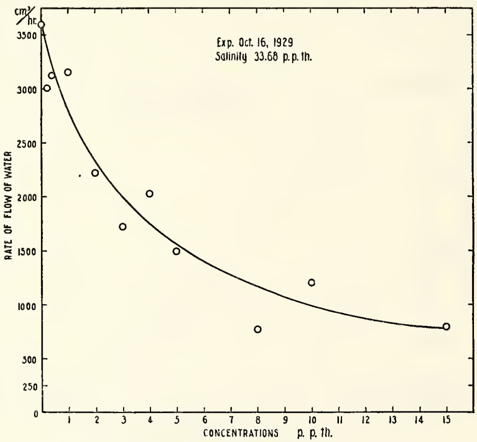

FIGURE 41.—Effect of sulphite liquor on the rate of feeding of *Ostrea gigas*. Temperature, 15.8–17.5° C.; pH, 7.9–5.7

Since red liquor is an acid solution, its effect on the activity of the ciliary epithelium could be attributed to the increase in hydrogen-ion concentration rather than to the presence of certain toxic substances. If the inhibition of ciliary activity were due to the increase in the acidity of the water, it would be a simple matter to counteract it by neutralizing the solution before it is discharged into the water. Unfortunately, this is not the case. In the experiment P13 (Table 6, fig. 40) the red liquor was neutralized by adding small amounts of NaOH until its pH was 7.1; various amounts of neutral liquor were added to the sea water, the pH of which was nearly constant (7.9 to 8.0), then the rate of flow of the water was measured. As can be seen from Table 6, neutral red liquor has a pronounced inhibitive effect on the rate of flow of water through the gills.

The conclusion seems inevitable that the liquor discharged by the pulp mill contains substances that affect the normal activity of the gill epithelium and consequently reduce the rate of feeding of oysters. It must be borne in mind that in the experiments just described, the oysters were kept in the solution of red liquor only for a brief period of time. It is quite possible that continuous exposure, even in very weak concentrations of this toxic substance, which fails to produce any visible effect immediately, may cause a general weakness of the organism, reducing its rate of metabolism and resulting in its higher mortality.

III. INVESTIGATIONS OF OYSTER MORTALITY IN OAKLAND BAY, WASH.

By H. C. McMillin

INTRODUCTION

The tide lands of lower Puget Sound have produced oysters for many generations. The springs along the shores were favorite camping sites for the Indians, and the shell piles near by bear evidence of the fondness of these people for the Puget Sound oyster. For many years after the coming of the white man the Indians continued to harvest the crop from the natural beds, but the industry passed to the white man through a system of land ownership and sale of rights.

Oysters were originally found in tide pools of the intertidal zone and on some of the low ground. In a few cases shallow channels also supported an abundant crop. At the beginning of intensive culture, the tide pools were enlarged or conditions were made more favorable for the oysters by removing the mussels and barnacles.

A new era in oyster culture in Puget Sound dates back to 1890, when the late J. Y. Waldrip leveled an area of ground, and constructed around it a dike of hand-split cedar boards. The buried ends of the pieces may still be found on Oyster Bay, where the original dike contributed to the knowledge of oyster culture. Within a short time the success of the new method was apparent. Dikes made of lumber, usually an inch thick, held in place by short stakes, appeared in almost every bay in the southern end of Puget Sound. Not all of the bottoms upon which dikes were built proved suitable for oyster culture, but successful methods of intensive culture were worked out in a short time for a large part of the intertidal zone.

Through several legislative acts the State has granted title to the oyster growers, and they now hold the land in fee simple. This has encouraged extensive improvement, and oyster land in Puget Sound is the most valuable of any oyster bottom in the nation, some being worth about $15,000 per acre.

Conditions in Oakland Bay are favorable to oyster culture. Tidal ranges of 8 to 18 feet cause strong currents; solid bottoms make easy the construction of permanent dikes; and gravel along the beach furnishes surfacing material. The making of new ground has continued slowly as the oystermen have spent their profits on leveling, diking, and surfacing. At present about two-thirds of the available ground is in shape to produce oysters. Each year the area is increased by new improvements. The abandoned dikes about the head of Oakland Bay and in Swindel Cove, do not represent a reduction of the industry, but are the results of early experimentation already discussed, and much of this ground will eventually be improved and cultured by modern methods. (Fig. 42.)

For many years Oakland Bay was an unfailing producer of seed oysters. A high production of adult oysters was maintained in the bay, and much seed was taken to other bays. A part of the State reserve has been improved with permanent dikes, and these beds have contributed a large sum annually to the oyster fund through the sale of seed. Privately owned areas adjacent to the "Narrows" obtained a good set of seed, which was an important source of income to the owner. There were, in reality, two oyster industries in Oakland Bay: One, the production of seed, which was carried on largely by the State; and the other, the raising of adult oysters, which engaged private enterprise. The adult oyster thrived well and the set was regular, although subject to annual variations. Cold weather during low tides has twice exacted a heavy toll of oysters. In 1916 it appeared that complete destruction had resulted. A few oysters, however, on the lower beds and in the channels survived, and the following summer a good crop of seed was obtained. This fact shows that a few adult oysters can, under favorable conditions, produce a good set of seed oysters.

Within the last three years conditions have changed radically. At the request of the oystermen a preliminary survey of the beds was made in May, 1929, which brought to light a few very definite facts. Many of the oysters were dying, and a majority on the lower beds were already dead. In the channels and on the undiked ground careful search revealed the presence of a few medium-sized oysters which were in the early stages of decomposition. Clams were working out of the ground, and they were in such a weakened conditions that one could pull the shell open with the fingers to examine the watery decomposing body within, which still showed signs of life. In the dikes of medium height a few large oysters were alive, but they showed no signs of the recent growth which would be expected. When these oysters were shucked they soon lost water from the body, and there remained a thin flabby piece of meat which had a decidedly bitter taste. On the higher beds the condition of the oysters was the same, but only a few had died recently.

This condition was not what one would expect from freezing, because, in that case, the higher and more exposed oysters would have suffered the most. In the present case, oysters on high, exposed ground showed no abnormal death rate.

No seed was obtained in 1927 and 1928, and judging from the condition of the oysters in May, 1929, it appeared doubtful, due to their emaciated condition, that any would develop reproductive material in that year. The oysters, apparently, did not remain open and feeding, as did those in adjacent bays. As soon as gray larvæ could be found in the mantle cavity of oysters in Totten Inlet, samples of water taken from Oakland Bay were introduced into normal sea water in which larvæ were living to determine if any reaction would follow. A few experiments, which will be discussed later, showed that larvæ were noticeably affected by Oakland Bay water.

SURVEY OF THE BEDS

An effort was made to determine the exact condition of the beds at the time of the investigation. (Figs. 44 and 45.) The area inside of each dike was examined and samples taken. A frame, inclosing a square yard, was placed on the bed, and all shells and oysters in the inclosure were taken up in a box for later examination. The samples were taken at random if the bed appeared to have an even distribution of oysters over its entire area. On low ground, where the bottom was uneven, or on beds then being worked, an effort was made to get adequate samples. The number ranged from 1 to 3 square yards in each dike. A number of records w re checked

Figure 42.—Taking up seed oysters on State reserve beds in Oakland Bay

by retaking, and no significant variation was found. A series of samples was taken at one time, depending upon the location and upon the height of the tide. The height of the surface of the bed above the lowest oyster-bearing level was measured and three figures were obtained from each sample: The volume of shells, the number of live oysters, and the number of dead oysters.

The first two determintions were easily made, but the number of dead oysters was more difficult to ascertain. There is no way of knowing how long any one oyster has been on the bed, but within a short time after death, the two valves, or halves, of an oyster shell break apart. We therefore, counted the number of specimens of

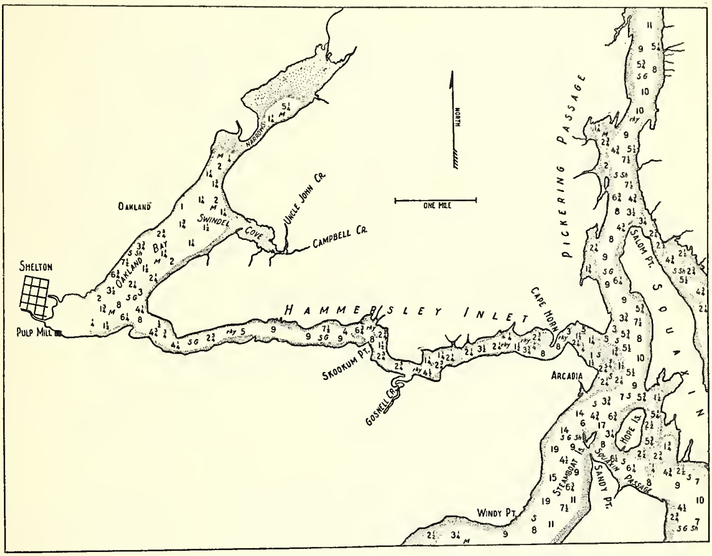

FIGURE 43.—General map of Oakland Bay, Hammersley Inlet, and Pickering Passage

which the two valves remained attached, and considered them as respresentative of the recently dead oysters. Doubtless, a number of valves were separated in handling, but this method appeared to be the only one available and by exercising due care a fair idea of the condition of the beds was obtained. The ratio between the number of dead and live oysters does not give as complete a picture of the loss that has occurred over the oyster beds as one would desire, nor is it equally reliable for all areas from which samples were taken. Where the current is swift, empty shells are carried away quite rapidly, making the apparent percentage of dead oysters very much lower than actually is the case. However, the results show to a satisfactory degree the general conditions as they existed at the time of the survey. (Fig. 46.)

Table 8 indicates that, in most cases, the mortality was proportional to the height of the bed. On all low ground the oysters have experienced a heavy mortality, while the higher beds show no abnormal death rate, except where the currents are slow. Beds, Nos. 86 to 93, in Swindel Cove are relatively high; but suffered a heavy death rate. These beds are behind the large gravel bar which partially closes the mouth of the cove, and are covered by a slowly moving eddy when the tide is high. On the northwest side of the creek which crosses the oyster beds in Oakland

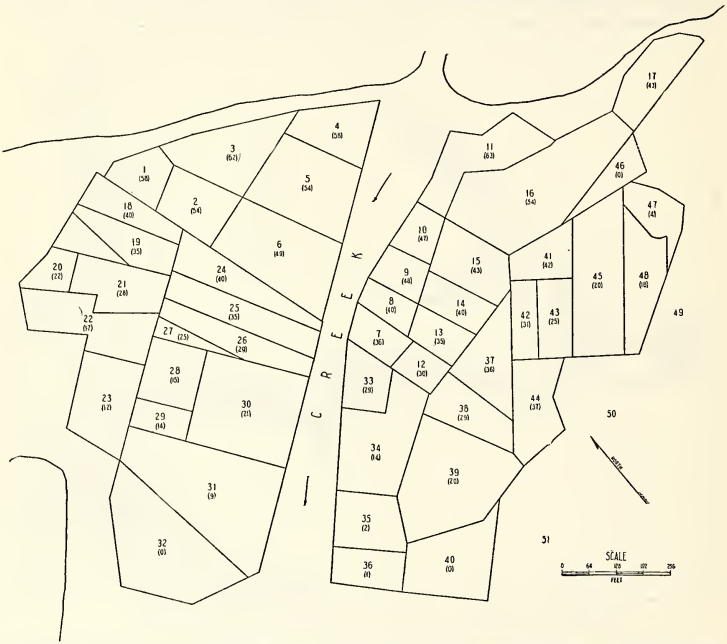

Figure 44.—Outline of oyster beds at head of Oakland Bay with number and height in inches corresponding with Table 1. Bed No. 40 is lowest diked area, surface of which was chosen as zero level

Bay, the private and State reserve beds have suffered a greater loss than those of the same level elsewhere. Here again the current is sluggish and the casualty high.

Records taken in Oyster Bay (Totton Inlet) in the same manner as the census of Oakland Bay are also shown in Table 10. In material that had been culled recently less than 18 per cent was found to be dead. One year after being worked, between 0.8 per cent and 12.5 per cent of the oysters may normally be found to have died as a result of handling, the percentage varying according to the number of seed oysters broken. In all cases where the loss is greater than 12.5 per cent the oysters have been recently handled and a large number of the small ones broken in process of removing the marketable adults.

TABLE 8.—*Census of oyster beds in Oakland Bay*

Dike number	Volume of shells	Area	Live oysters	Dead oysters	Dead	Height[1]	Dike number	Volume of shells	Area	Live oysters	Dead oysters	Dead	Height[1]
	Bushels	*Sq. yds.*			*Per cent*	*Inches*		*Bushels*	*Sq. yds.*			*Per cent*	*Inches*
1	0.43	3	131	56	30	58	49	.95	1	203	97	32	0
2	.19	2	32	52	62	54	50	.48	2	87	106	55	0
3	.28	2	60	5	8	62	51	.16	4	1	3	75	0
4	.53	2	314	35	1	58	52	.20	1	53	81	60	0
5	.38	2	85	13	15	54	53	.61	1	362	267	43	4
6	.36	2	132	40	28	49	54	.54	1	119	156	57	17
7	.65	1	210	44	17	35	55						21
8	1.21	2	555	89	14	40	56	.38	1	172	142	45	21
9	.65	1	155	122	44	48	57	.40	1	85	88	51	6
10	.40	1	309	26	8	47	58	.50	2	83	239	65	8
11	.76	2	439	54	11	63	59	.64	1	162	76	32	13
12	.74	2	64	32	33	30	60	.29	1	66	166	72	29
13	.65	1	219	69	25	35	61	.47	1	192	74	28	40
14	.83	2	506	73	13	40	62	.61	1	460	95	17	34
15	.74	1	352	58	14	43	63	.28	1	203	176	46	30
16	.77	1	248	21	8	54	64	.24	1	116	104	47	6
17	.68	1	318	236	43	43	65	.38	1	95	96	51	14
18	.35	1	216	60	22	40	66	.57	1	153	146	49	9
19	.40	1	22	164	88	35	67	.53	1	61	122	67	18
20						22	68	.63	1	48	64	57	25
21	.67	2	52	272	84	28	69	.52	1	55	65	54	18
22						17	70	.29	1	10	40	80	22
23	.40	1	18	88	83	12	71	.52	1	81	81	50	12
24	.57	2	34	42	55	40	72	.24	1	35	28	44	22
25	1.04	3	69	132	66	35	73	.18	1	22	87	80	36
26	.83	2	114	288	72	29	74	.54	1	42	78	65	22
27						25	75	.59	1	82	133	62	42
28						15	76	.14	1	17	71	81	28
29						14	77	.24	1	48	66	58	24
30	.28	4	45	120	74	21	78	.24	1	35	108	75	32
31						9	79	.82	1	141	459	76	33
32	.38	2	0	80	100	0	80	.67	1	428	101	19	34
33	.39	1	218	292	57	29	81	.12	2	8	92	92	34
34	.08	2	7	38	85	14	82	.64	1	102	183	64	13
35						2	83	.35	1	195	87	31	12
36	.20	1	91	86	49	1	84	.38	1	81	176	68	20
37	.47	1	42	31	42	36	85	.42	1	166	145	47	35
38						29	86	.05	3	5	28	85	29
39	.76	2	134	254	65	20	87	.35	1	18	99	85	25
40	.16	1	18	19	52	0	88	.06	1	80	58	42	31
41	.73	2	279	289	51	42	89	.13	2	22	127	85	32
42	.81	1	207	189	48	31	90	.13	1	9	56	86	31
43	.52	1	196	181	48	25	91	.30	1	25	104	81	28
44						37	92	.14	1	2	67	97	32
45	.70	1	171	386	69	20	93	.24	1	4	58	94	33
46						0	94	.30	1	168	143	46	0
47	.95	1	99	127	56	4	95	.19	2	15	16	51	0
48	.68	2	232	660	74	18							

[1] Above lowest oyster bearing level.

In order to obtain a mathematical expression for the relation of the height of the beds to the number of adult oysters and percentage of mortality in Oakland Bay, the coefficient of correlation was calculated. Samples were taken on a line extending from high water to low water directly across the beds. (Table 9.) The results of three such series were combined, making a total of 21 stations. Standard methods of computations gave a correlation coefficient ("r") between height and per cent of dead oysters of -0.6996 ± 0.075, showing that the loss is very closely associated with the height of the beds, the largest number of dead oysters being on the low ground. Between height of bed and number of living oysters the coefficient of correlation was 0.5866 ± 0.096, showing that the number of live oysters increased directly with the height of the bed. The values thus obtained are relatively high for biological data. They are respectively 9 and 6 times their probable error, which shows that the correlation is significant. Similar treatment of figures obtained from beds in Totten Inlet (Oyster Bay) showed no correlation between the number of dead oysters and position of beds from which the sample was taken ($r = -0.3316 \pm 0.226$) but a high positive correlation between the number of live oysters and position ($r = 0.8166 \pm$

0.005). (Table 10.) The actual number of living oysters on the high beds were similar but the lower beds of Oyster Bay were more heavily populated. A total of 84

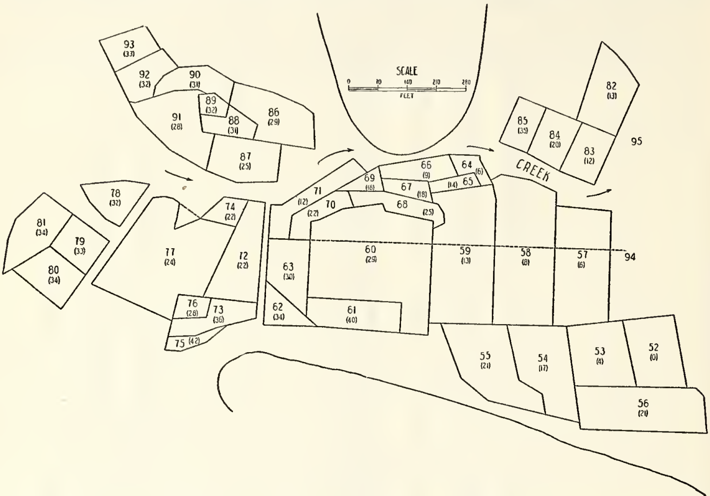

FIGURE 45.—Outline of oyster beds in Swindel Cove. Number of bed with height in inches in parenthesis corresponding with Table 1. Bed No. 52 is lowest diked area, surface of which was chosen as zero level. Beds Nos. 52 and 40 (fig. 44) are at the same level

samples taken in Oakland Bay showed an average volume of 0.538 bushels per square yard, while in Totten Inlet (Oyster Bay) 10 samples gave an average of 0.423 bushels.

TABLE 9.—*Correlation table of 21 station in Oakland Bay showing relations between height of bed and per cent of dead oysters and between height of bed and number of live oysters*

Dike No.	Height [1]	Dead	Live oysters	Dike No.	Height [1]	Dead	Live oysters
	Inches	*Per cent*			*Inches*	*Per cent*	
40	0	52	52	7	35	17	210
94	0	46	168	13	35	25	219
36	1	49	91	37	36	42	31
57	6	51	85	14	40	13	253
58	8	65	119	8	40	14	278
59	13	32	162	15	43	14	352
34	14	85	7	10	47	8	309
39	20	65	65	16	54	8	248
33	29	57	218	11	63	11	439
60	29	72	66				
63	30	46	203	"r" on height		−0. 6996±0. 075	+0. 5866±0. 096
62	34	17	460				

[1] Above lowest oyster-bearing level.

TABLE 10.—*Census of oyster beds in Totten Inlet (Oyster Bay)*

Dike No.	Volume of shells	Area	Live oysters	Dead oysters	Doad	Height [1]	Dike No.	Volume of shells	Area	Live oysters	Dead oysters	Dead	Height [1]
	Bushel	*Sq. yd.*			*Per cent*	*Inches*		*Bushel*	*Sq. yd.*			*Per cent*	*Inches*
O1	0.68	1	367	3	0.8	63	O3	.23	1	280	40	12.5	10
O5	.35	1	405	23	5.4	51	B1	.47	1	150	6	5.1	10
B5	.69	1	410	29	6.6	41	B6	.35	1	132	8	5.7	0
B4	.57	1	292	31	9.6	30							
B3 [1]	.43	1	140	25	17.8	22	"r" on height			0.8166±0.085		−0.3316±0.226	
O4 [1]	.18	1	232	48	17.1	18							
B2 [1]	.28	1	164	32	16.3	15							

[1] Above lowest oyster bearing level.

The total population of adult oysters in a few areas in Oakland Bay was greater than on any bed in the other bays. In Swindel Cove two beds averaged more than

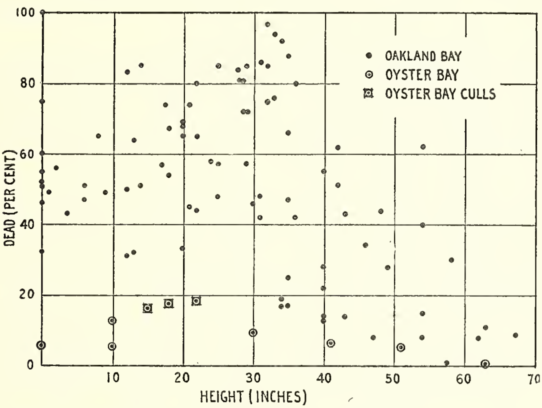

FIGURE 46.—The height of the oyster beds in Oakland Bay, Swindel Cove, and Oyster Bay in relation to the proportion of dead oysters

400 adult oysters per square yard, and numerous small areas outside of the dikes were as densely populated.

Further comparisons might be made with improved beds in other bays, but the conditions which now exist in Oakland Bay are peculiar to that locality, and unique in the history of oyster culture of Puget Sound. No similar set of conditions has ever been known in the vicinity. Various reports have been investigated regarding abnormal losses of oysters in a limited locality, but investigation showed they were in no way parallel cases with the one now under consideration. Where abnormal death rate has occurred in the past, it has invariably been when the oysters were outwardly in good condition. In a small section of Skookum Inlet the oysters died very rapidly for a short time. At the beginning of the time of high death rate, the oysters were in excellent condition and the growers were receiving a special bonus above the regular price for their catch. In no other case has the oyster appeared to remain closed, become thin, and ceased to grow before dying. Nor has any condition been so prolonged as that existing now in Oakland Bay.

ECOLOGICAL OBSERVATIONS

SPAWNING

No set of oysters has been obtained in Oakland Bay for three years, and at present, the live oysters are in an abnormal physical condition. During the summer of 1929 reproductive products were formed only in a very few individuals. Three specimens containing eggs in the segmentation stage were found, and although a great many oysters were examined during the course of the summer, none was found which contained shelled larvæ (commonly called "black spawn") in the mantle cavity.

Failure of set has been experienced in other bays. Eld Inlet (Mud Bay), prior to 1928, was considered to be poor setting ground. The set in Hood Canal and North Bay was also very light for several years. However, in each case outside of Oakland Bay, the oysters developed sexual products, and spawned normally. Either natural water conditions made the mortality of larvæ high, or proper cultch was lacking. At any rate, in all cases a few seed were found each year.

In May, 1929, over 200 bushels of adult oysters were moved from North Bay to Oakland Bay. They were in good condition and spawned; the larvæ were carried the proper time, and liberated apparently in good condition. So far as is known, these were the only oyster larvæ in Oakland Bay during the season, and not a single seed oyster has been found on shells on the beds. Special spat collectors developed by the Bureau of Fisheries were placed on various parts of the bed and caught 25 seed oysters on 2½ bushels of shells, an average of 1 spat to 1,000 shells.

The failure of the set was probably due to two or more related factors. The adult oysters failed to develop sexual products, which precluded any chance of spawning, and the conditions which affected the adult oysters probably prevented normal development of the larvæ from introduced oysters.

Water samples, taken in April from Oakland Bay and held in tightly stoppered bottles, were examined to determine their affect on oyster larvæ. Dilutions of one-sixth and one-tenth were tested with normal sea water for control. Samples of water taken near the southern end of Oakland Bay caused an instantaneous reaction in which all larvæ closed their shells and sank to the bottom. A sample taken over the oyster beds produced a less sharp reaction. A few larvæ were swimming about after one day in the weaker solution, but later observations showed no movement. In normal sea water the larvæ continued to live and swam about the dish continually. The water was changed at bi-weekly intervals, and no dead larvæ were noted for nearly three weeks.

It is probable, therefore, that water conditions in Oakland Bay were unfavorable to the larval oyster and resulted in the death of nearly every one.

GROWTH OF BARNACLES

Not only the oysters in Oakland Bay have been affected, but other organisms as well. Some forms have, apparently, been stimulated; others suppressed. To illustrate this point we might refer to the floating equipment used about the oyster beds. It is a universal practice to scrape and repaint floating equipment at regular intervals, for, under normal conditions those parts of objects which are immersed in sea water are quickly covered with plant or animal growth. Boats and scows used on the oyster beds have always been cleaned and repainted at least once a year, but in the last three years no growths have appeared, and the work of reconditioning has

been found unnecessary. Since these pieces of apparatus do not leave the oyster beds, these facts indicate that abnormal conditions exist in the water over the oyster beds.

Barnacles, mussels, and hydroids normally found on floating euqipment used about the oyster beds are not noticeably affected by normal fluctuations in the physical factors in the environment. They are found where the salinity is higher or lower than that ever found in Oakland Bay. They occur to the north and to the south and thrive in water which is both warmer and colder than near the oyster beds. We can assume, therefore, that fluctuations in temperature and salinity do not account for their absence from the floating equipment referred to; domestic sewage does not appear to affect these organisms seriously, and one looks upon the annual crop as a matter of course. Their absence, therefore, from the oyster beds indicates that abnormal factors, other than temperature, salinity, or sewage, must be considered in relation to the condition in Oakland Bay at the present time.

PLANT GROWTH

It is evident that the growth of some plants was stimulated by the conditions existing in Oakland Bay during the winter of 1928–29, and the spring and summer of 1929. The chain diatom *Melosira borreri,* Greville, grow in dense masses over some sections of the oyster beds. Where the current was slow over beds that were between 2 and 4 feet above the lowest oyster dikes, it formed a mat that completely covered the oysters and shells. This diatom is present at all times in small amounts on oyster beds of the same level in near-by bays, but it is evident that the growth was greatly stimulated in this particular place.

The distribution of this plant growth apparently bore no relation to the mortality of the oysters. Many beds were free from it, and had a high death rate of oysters. The lower grounds, which suffered the most in the recent disturbance, were not affected by *Melosira* at all. Some beds that were covered with a heavy mat experienced almost a total loss of oysters, while others showed nothing abnormal.

It is concluded, therefore, that *Melosira* does not injure the oysters, but, that its dense growth indicates a disturbed condition of the water in which it normally grows in small amounts.

POSSIBLE EFFECTS OF LOG STORAGE

The effect of logging operations and sawmill waste upon oysters is a much debated question. In Oakland Bay sawdust is absent, and can not be considered as affecting the oysters. There are, however, at all times, many log booms in the bay, and they have been blamed for oyster mortality. Certain chemicals in the logs are supposed to pass into solution and to affect the oysters. In Eld Inlet the log storage is proportionally greater than in Oakland Bay; new logs are constantly being added and any chemicals that leach out of the timber would be in high concentration in this place. However, the water is normal in color and the oysters which live in the bay prove that no harmful chemicals are present. In coves and lagoons where the bottom is covered with decaying vegetation and many tree trunks are strewn about, one would expect the wood chemicals in solution to be at a maximum. Such places are known to produce a natural set of oysters which grow and mature normally. Nothing about their condition suggests any effect of wood chemicals.

The oyster larva will set upon pieces of hemlock bark recently stripped from a tree. In this case the oyster comes in direct contact with the phloem tissue which

carries in a soluble state the tannins, resins, and other chemicals which might leach out into the water. If injurious chemicals pass into solution from logs or bark, one would expect to find evidence of a negative reaction of oyster larvæ toward bark.

Since no direct evidence has been found to show that logs or logging operations injure oysters, and observations indicate that no injury is probable, it can be safely assumed that the serious condition now existing in Oakland Bay is in no way related to the presence of log booms in the adjacent waters.

POSSIBLE EFFECTS OF DOMESTIC SEWAGE

Within the last few years Shelton has had a fourfold increase in population. Not all of the new residence areas have been connected with the sewer system emptying into Oakland Bay, and the disposal of sewage has not increased proportionally with the population. Dr. W. M. Beach, health officer of Shelton, states that domestic sewage disposal has increased less than 20 per cent in the last four years. The oyster beds are at the opposite end of the bay from the sewer outlet, and the State sanitary engineer was unable to find evidence of domestic sewage pollution over the oyster beds.

On the mud flats near the city of Olympia oysters thrive in water that is heavily polluted with domestic sewage. Also in Liberty Bay and Sinclair Inlet, they live in contaminated water. Legal restrictions are necessary to prevent the marketing of oysters from such beds, but reproduction and growth are apparently normal. Therefore, sewage is evidently not a factor for consideration in the present problem. At any rate, it is improbable that the small increase has a bearing on the recently developed condition of the oysters.

SULPHITE WASTE LIQUOR POLLUTION

As a result of the survey of conditions in Oakland Bay some definite conclusions are forced upon us: (1) The oysters are dying at an alarming rate; no set has been obtained in three years, and consequently, the oyster industry is at a standstill. (2) The growth of at least one marine plant is greatly stimulated, and that of some animals is prevented. (3) Barnacles, clams, mussels, and hydroids which tolerate a wide range of physical conditions have apparently not reproduced in Oakland Bay in the last three years. (4) There is no indication that this condition has been caused by abnormal temperature, or by a varying salt content of water. (5) Log storage, sawdust, or domestic sewage probably could not have caused this great, sudden, and unique change in the fauna and flora of the vicinity. (6) There remains one factor to examine; that of the sulphite waste liquor added to the water of Oakland Bay by the Rainier Pulp and Paper Co.

During the construction of this mill an examination of Oakland Bay waters was made, and the *unpublished* report of H. W. Nightingale, State sanitary engineer, of January 21, 1927, states:

> From this preliminary investigation it is concluded that the mill is so located with respect to the shell-fish growing areas that the discharge of its waste will create a potential danger. From the standpoint of the chemical determinations on the sea water in Oakland Bay and Hammersley Inlet the conditions now appear to be normal for the support of the marine life.

As a result of investigations it was recommended that a portion of the waste liquor be taken out of Oakland Bay either by scow or by pipe line, and a pipe line was constructed before the mill began operations. Some of the waste liquor was pumped out of the bay, and some was dumped into the bay at the mill.

There is no way of determining the volume of liquor discharged at the mill or pumped to the discharge tanks. The following quotations are taken from the unpublished daily reports of State Fishery Inspectors C. C. Rice and E. Hart:

> On March 14, 1929, we visited the discharge tanks at the end of the pipe line and found them empty, and no evidence of them having been used recently. On March 15, 1929, we visited the discharge tanks at the end of the pipe line and found them about three-fourths full of red liquor (175,000 gals.), which had been pumped into the discharge tanks during the night before, and which was released into Hammersley Inlet at high tide (8.34 a. m.). We visited the discharge tanks again at 7.00 p. m., and found them empty, nothing having been pumped into the tanks during the day.

On the morning of March 16 the same inspectors found the tanks one-third full of red liquor (70,000 gallons), and the same amount at 6.40 p. m. the same day. No liquor was pumped on March 17, and only a little (not over 20,000 gallons) on March 18. Thus we see that, according to the reports of State inspectors, in a period of 5 days, during which the plant was under constant observation and produced about 1,400,000 gallons of waste liquor, less than 20 per cent of the total was pumped out of Oakland Bay; and during 2 days out of the 5 very little, if any, was disposed of through the pipe line.

Conditions on the oyster beds changed rapidly after the mill started operations. Heretofore, the water was clear, and the oystermen were able to spread shells without the aid of marking stakes. Soon it was impossible to see bottom except in very shallow water, and the normal green color of the water was replaced by the coffee-brown shade characteristic of dilute sulphite waste liquor. During the summer and autumn of 1929 a large proportion of the liquor was disposed of through the pipe line, and the oysters resumed growth, and a very few seed were obtained. During these observations (December 9, 1929) a sudden appearance of deeply discolored water at the oyster beds led to inquiry at the pulp mill concerning discharges of concentrated liquor into the bay at the plant. The foreman stated that about 6,000 to 7,000 gallons of concentrated liquor had been released through the sewer about 36 hours before the appearance of the brown coloration on the oyster beds.

Since the pulp mill was located at one end of Oakland Bay and the oyster beds at the other, with the outlet on one side of the bay between the two, a study of the tidal currents was necessary to determine whether the liquor discharged at the mill might reach the oyster beds. (Fig. 48.) The currents in the bay were traced by means of an Eckman current meter which registers the direction and velocity of the current at any depth to which it is lowered.

It was learned that the flood tide causes a rapid flow of water into Oakland Bay from Hammersley Inlet, and that the reverse movement takes place at nearly the same velocity, that is about 2.2 feet per second on the surface. The main stream of the current passes across the southern end of Oakland Bay, and along the northwest shore toward and through the "Narrows" where the oyster beds are located. The out-going tide is at the first a general surface movement toward the head of Hammersley Inlet, but gradually the flow of water from the head of the bay causes a strong current down the center of the bay past the mouth of Hammersley Inlet, and then back along the south shore before it leaves Oakland Bay. (Fig. 47.) These currents are easily observed by the movement of drift and are well known to the boatmen of the vicinity.

The bottom currents differ in direction and velocity from the surface currents. At the entrance to Oakland Bay the water is about 50 feet deep at low water. A deep channel crosses the lower end of the bay, follows the northeast shore, and runs

out about halfway up the bay. As the water enters Oakland Bay the current is confined to the surface by flowing over a shallow stretch of bottom in the upper end of Hammersley Inlet. (Table 12.) After the surface water has attained a velocity of about 2 feet per second, the lower strata slowly begins to move, but the velocity never exceeds 0.6 foot per second at the entrance of Oakland Bay. Farther along

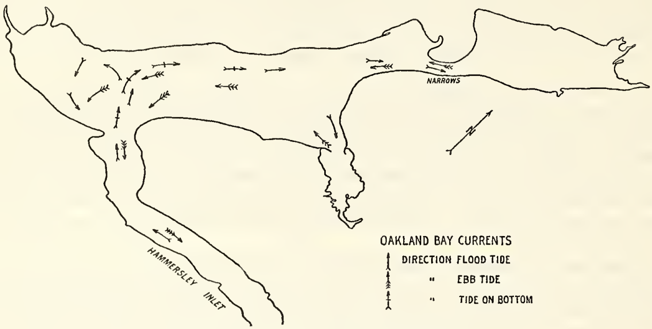

FIGURE 47.—Direction of currents in Oakland Bay

the channel the current of moving water becomes deeper and in front of the Union Oil Co. in over 35 feet of water the flood tide current has an equal velocity from surface to bottom. The flood current continues much longer on the bottom than on the top, and there is little or no reverse in the direction of the current with the ebb tide. (Fig. 49, Table 11.) In other words, the currents caused by the ebb tide

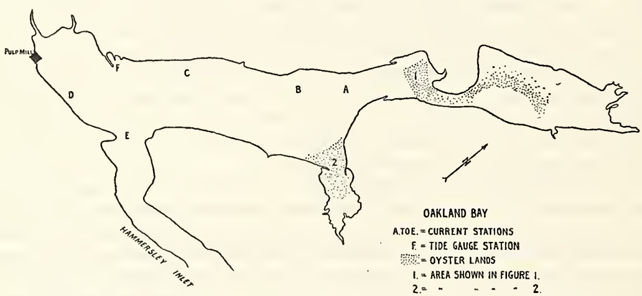

FIGURE 48.—Principal stations for current observations and tide recording station in Oakland Bay

are more closely confined to the surface than flood tide currents. The surface current of the flood tide crosses the bay on a diagonal line near the head, and continues through the "Narrows." The bottom current reaches the end of the channel and spreads out on the bottom, but continues directly up the bay to the oyster beds at the head of Oakland Bay.

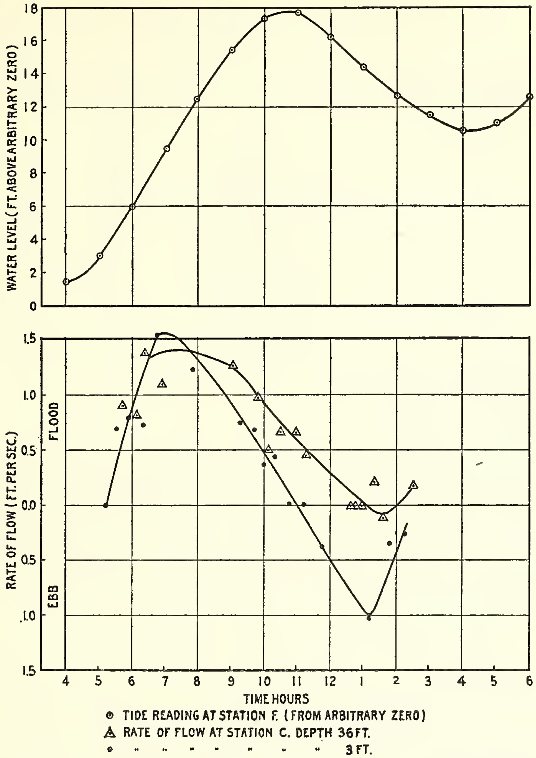

FIGURE 49.—Current velocities at station C and height of tide at station F. November 21, 1929

TABLE 11.—*Currents at station "C," Oakland Bay, November 21, 1929*

Time	36 feet	Direction	Time	36 feet	Direction	Height of tide[1]
	Feet per second			*Feet per second*		*Feet*
5.15 a. m.	([2])	Flood.	5.30 a. m.	0.69	Flood	4.2
5.40 a. m.	0.90	Do.	5.55 a. m.	.79	do	5.3
6.05 a. m.	.81	Do.	6.20 a. m.	.72	do	7.0
6.25 a. m.	1.39	Do.	6.45 a. m.	1.54	do	8.5
6.55 a. m.	1.10	Do.	7.55 a. m.	1.23	do	12.3
9.00 a. m.	1.25	Do.	9.15 a. m.	.74	do	16.0
9.25 a. m.	1.07	Do.	9.40 a. m.	.68	do	16.8
9.50 a. m.	.98	Do.	10.00 a. m.	.36	do	17.3
10.05 a. m.	.50	Do.	10.20 a. m.	.43	do	17.6
10.30 a. m.	.66	Do.	10.45 a. m.	([2])	do	17.8
10.55 a. m.	.66	Do.	11.07 a. m.	([2])	do	17.5
11.15 a. m.	.44	Do.	11.45 a. m.	.39	Ebb	16.8
11.35 a. m.	.39	Do.	12.17 p. m.	.65	do	15.7
11.55 a. m.	([2])	Do.	1.10 p. m.	1.04	do	14.0
12.35 p. m.	0	Do.	1.50 p. m.	.35	do	12.9
12.45 p. m.	0	Do.	2.15 p. m.	.27	do	12.3
12.53 p. m.	0	Do.				12.0
1.20 p. m.	.20	Do.				
1.35 p. m.	.12	Ebb.				
2.00 p. m.	0	Flood.				
2.30 p. m.	.18	Do.				

[1] Above arbitrary zero. [2] Too slow to measure rate.

TABLE 12.—*Current velocities December 1, 1929, at station E* [1]

[Total depth 48 feet]

Time	Height of tide [2]	36 feet	Surface	12 feet	Direction	Time	Height of tide [2]	36 feet	Surface	12 feet	Direction
	Feet						*Feet*				
10.45 a. m.	13.1		0.59		Ebb.	3.15 p. m.	13.7			0.36	Flood.
11.00 a. m.	12.7	[3] 0.05			Do.	3.30 p. m.	14.1			.32	Do.
11.15 a. m.	12.3	.25			Do.	3.45 p. m.	14.6		2.23		Do.
11.30 a. m.	11.9	[3] .05			Do.	4.00 p. m.	15.0		1.89		Do.
11.45 a. m.	11.6	.05			(4)	4.15 p. m.	15.5		1.00		Do.
12.00 m.	11.3	[3] .03			(4)	4.30 p. m.	15.9		1.67		Do.
12.15 p. m.	11.1	.28			Ebb.	4.45 p. m.	16.2		1.47		Do.
12.30 p. m.	10.9	[3] .13			Do.	5.00 p. m.	16.4		1.98		Do.
12.45 p. m.	10.7	[3] .02			Do.	5.15 p. m.	16.5		1.47		Do.
1.00 p. m.	10.6	.15			(4)	5.30 p. m.	16.6		1.83		Do.
1.15 p. m.	10.7	.33			Ebb.	5.45 p. m.	16.6		1.54		Do.
1.30 p. m.	10.8	.25			Do.	6.00 p. m.	16.5		.90		Do.
1.45 p. m.	11.0	.32			Do.	6.20 p. m.	16.2		.68		Ebb.
2.00 p. m.	11.4		.73		Flood.	6.35 p. m.	15.8	0.20			Do.
2.15 p. m.	11.9	[3] .02			(4)	6.50 p. m.	15.4		1.01		Do.
2.30 p. m.	12.3	.02			Ebb.	7.00 p. m.	15.0		1.66		Do.
2.45 p. m.	12.8	.23			Do.	7.15 p. m.	14.6		1.66		Do.
2.50 p. m.	12.9	.23			Do.	7.30 p. m.	14.0		1.12		Do.
2.55 p. m.	13.0	.28			Flood.	7.45 p. m.	13.6		1.16		Do.
3.00 p. m.	13.2		2.18		Do.						

[1] Observations by member State fisheries staff.
[2] Above arbitrary zero.
[3] Approximate, below accurate range of current meter.
[4] No direction recorded by instrument.

The concentrated liquor is heavier than sea water (specific gravity 1.05). When it is released, as on December 9, it sinks to the bottom as it cools and probably accumulates in the deep hole near the entrance to Oakland Bay. From there it must pass slowly up the bay with the bottom currents, and reach the upper end of the bay before any great amount of it has had a chance to become mixed with the water which leaves Oakland Bay on the ebb tide. For this reason it was possible to notice changes in the water over the oyster beds in a short time after a small amount (6,000 to 7,000 gallons) had been discharged at the mill.

CONCENTRATION OF LIQUOR IN OAKLAND BAY

Continued addition of waste liquor to the bay would cause a gradual increase in concentration until an equilibrium is reached. The concentration of liquor at equilibrium, or the maximum amount of liquor which would remain in the bay, is proportional to two factors: (1) The amount added daily, and (2) the proportion of water lost daily by tidal action. To illustrate: If 1 acre-foot of liquor be discharged daily at the mill, and one-twentieth of the water in the bay be renewed each 24 hours by tidal action, at equilibrium 20 acre-feet of liquor would be present in the bay. Assuming complete mixing of liquor and water, 1 acre-foot of liquor (1/20 of 20) would be lost each day, and the same amount would be added. Therefore, an approximation of the amount of water lost each day from Oakland Bay will give us an index to the possible concentration of liquor in the bay.

It was therefore necessary to determine the amount of water in Oakland Bay, and the amount lost on each tide. The volume of water in the bay at low tide was calculated from figures given by United States Coast and Geodetic Survey chart and tidal records. The areas of nine parallel cross sections were determined from figures given in Table 13 by reproducing the contour of the bottom of the bay between the shores and calculating the area of water in each plane. (Fig. 50, Table 13.) The volume was determined in a similar way using the areas of the cross sections and the distance from the lower end of the bay as coordinates and calculating the

area under the curve. The results indicated that there were 11,672.6 acre-feet of water in Oakland Bay at low tide. By measuring the number of acres in the bay and calculating the average depth, a less reliable figure was obtained for the volume of the bay. It was 11,427 acre-feet and serves as a check on the first calculation. It was also found that 718 acre-feet of water remained in the deep hole above the

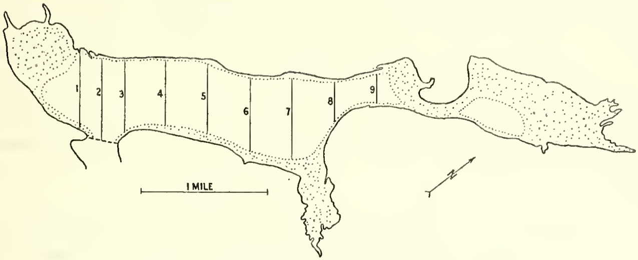

FIGURE 50.—Locations of cross sections used in volume determinations

"Narrows" in what is locally called "the head of the bay." We have therefore an indicated volume of 12,390 acre-feet of water in the bay at low tide. (Table 15.)

TABLE 13.—*Depths and distances of cross sections of Oakland Bay. Locations shown in Figure 50*

[Distance calculated from northwest shore at zero tide level. All measurements calculated in feet]

Section 1		Section 2		Section 3		Section 4		Section 5		Section 6		Section 7		Section 8		Section 9	
Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth	Distance	Depth
1,000	10.3	1,000	18.4	516	30.5	300	39.0	580	18.6	775	10.8	1,650	9.0	1,000	9.9	1,000	4.5
2,000	17.5	2,000	48.0	1,200	24.2	1,800	9.0	2,000	7.2	2,000	8.5	------	------	------	------	------	------
3,000	25.5	3,000	48.0	2,450	19.3	2,660	10.5	3,000	10.0	3,000	4.5	------	------	------	------	------	------
3,100	0	3,440	0	3,040	0	2,760	0	3,100	0	3,110	0	3,414	0	1,840	0	1,200	0

TABLE 14.—*Area of cross sections of Oakland Bay and distance calculated from southwest end of bay at zero tide level, calculated from Table 13*

Section No.	Area	Distance	Section No.	Area	Distance
	Square feet	*Feet*		*Square feet*	*Feet*
1	41,775	2,000	6	22,754	10,000
2	111,620	3,000	7	15,363	12,000
3	59,450	4,000	8	9,108	14,000
4	50,760	6,000	9	2,835	16,000
5	32,812	8,000	10	0	17,000

NOTE.—Volume 508,421,100 cubic feet or 11,671.7 acre-feet.

TABLE 15.—*Area of surface and volume of water in Oakland Bay*

Portion	Area at high tide	Volume	
		Low tide	High tide
	Acres	*Acre-feet*	*Acre-feet*
Main bay	935	11,672	21,583
Shelton boom	141	(1)	747
Swindel Cove	91	(1)	485
Tide flats head of bay	381	(1)	2,030
Deep above narrows	80	718	1,566
Total	1,608	12,390	26,411

[1] Bare at low tide.

The average tidal range at the Shelton Dock is 10.6 feet. To calculate the volume of water at high tide, it was assumed that the tide land of the bay would have an average depth, between zero tide level and high tide, of one-half this range, or 5.3 feet. The 613 acres of tide land, therefore, would be covered with 3,259 acre-feet of water. The 1,015 acres not bare at low tide would have an additional volume of 10,759 acre-feet at high tide and a total of 23,149 acre-feet. There is, therefore, an indicated volume of 26,411 acre-feet in the bay at high tide. Since there are, of necessity, irregularities in the bottom which can not be measured in calculations, the volume at high tide is considered to be 26,000 acre-feet and 12,000 acre-feet at low tide. Therefore, on the average, 14,000 acre-feet of water leave Oakland Bay at each tide. All of this water could be contained in Hammersley Inlet and might return with the tide, but such is not the case. On the smaller tides most of the water returns, only a small portion being lost by mixing with the waters in the eddies. (Fig. 43.)

An effort was made to estimate the volume of water which is lost from Oakland Bay by tidal action. Hammersley Inlet receives an average of 14,000 acre-feet of water from Oakland Bay on the ebb tide and returns a similar amount on the flood tide. If the same water which leaves Oakland Bay does not return, it is lost by mixing with Hammersley Inlet water or by entering Pickering Passage where it is carried into Case Inlet and does not return on the ebb tide, the most of which may come through Squaxin Passage. (Fig. 43.) In other words, the tidal action in Hammersley Inlet is an oscillating movement in which water moves from Oakland Bay into Hammersley Inlet and back again. Some consideration must be given to the loss of Oakland Bay water by mixing in Hammersley Inlet. Each cove and stream mouth was observed on two to five occasions, and it was estimated that they retained less than 50 acre-feet of water at high tide which may have been derived from Oakland Bay. Exclusive of this amount, Oakland Bay water which does not leave Hammersley Inlet returns on the ebb tide to the bay. We must also bear in mind that the principal discharge of the sulphite liquor is at the lower end of Hammersley Inlet; hence the water which replaces that lost into Hammersley Inlet is itself polluted.

An attempt was made to determine when ebb tide currents would carry water from Oakland Bay through Hammersley Inlet into Pickering Passage. It was found that on a normal ebb tide preceding low water recorded as −1.3 feet at Seattle, water from Oakland Bay may reach Pickering Passage. By drifting in a skiff down Hammersley Inlet and maintaining a position as nearly as possible in the swiftest current, it was found that the boat did not reach the passage before low water. It is recognized that a certain inaccuracy is introduced by the use of a boat for this purpose. However, the work was carried out on a calm day when air resistance would be at a minimum and the drift was with the prevailing air currents. These errors were more than counterbalanced by keeping the boat in the swift current and out of the eddies. Floating débris drifting at random did not cover an equal distance. There are usually about 50 tides a year which are lower than −1.3 feet (reference station, Seattle); these average −2.5 feet in height. On such a tide it was found that by starting at the entrance of Oakland Bay with the beginning of the ebb and drifting in the strongest part of the surface current, one could arrive at the lower end of Pickering Passage two hours before low water.

At approximately the time when the water from Oakland Bay could have reached Pickering Passage, as estimated in the manner just described, the rate of the flow of

the current at Cape Horn was measured by means of drifting floats. The speed of the current was 1.6 feet per second. Previous to low slack water, not over 5,400 linear feet of current passed the cape; the channel has a cross sectional area of 4,000 square feet; therefore, not over 21,600,000 cubic feet or 496 (approximately 500) acre-feet of water could have been lost. Once again we must bear in mind that the water which replaced that lost into Pickering Passage was necessarily polluted with sulphite waste liquor, due to the discharge of the pulp liquor at the lower end of Hammersley Inlet and its constant presence in the vicinity.

We have, therefore, an indicated loss from Oakland Bay of 50 acre-feet of water per tide, or about 700 acre-feet per week for normal tides, and an additional 500 acre-feet for one extreme tide, a total of 1,200 acre-feet per week. In order to use even numbers we can consider 1,400 acre-feet per week, or 200 acre-feet per day as the maximum average loss. Therefore, the volume of water contained in the bay is 130 times the amount lost daily. With this figure we can estimate the equilibrium concentration of liquor in Oakland Bay following the continued dumping of any amount of liquor. (Table 16.) The continued dumping of 75,000 gallons of liquor per day at the mill would result in a concentration of 1 part of liquor to 870 of water at equilibrium. Discharge of 280,000 gallons daily at the mill would result in a concentration of 1 to 233 in the bay.

TABLE 16.—*Accumulation of sulphite waste liquor in Oakland Bay*

Assumed daily discharge	Assumed daily discharge	Theoretical accumulation at equilibrium	Equilibrium concentration, liquor to sea water	Assumed daily discharge	Assumed daily discharge	Theoretical accumulation at equilibrium	Equilibrium concentration, liquor to sea water
Gallons	*Acre-feet*	*Acre-feet*		*Gallons*	*Acre-feet*	*Acre-feet*	
50, 000	0. 15	19. 48	1–1300	200, 00	.61	79. 06	1–329
75, 000	.23	29. 86	1–870	250, 000	.77	99. 71	1–261
100, 000	.31	40. 23	1–646	280, 000	.86	111. 32	1–233
150, 000	.46	59. 66	1–436	320, 000	.98	126. 77	1–205

The concentration of liquor in the bay at any one time after operations started may be calculated by standard mathematical processes:

If a = the number of acre-feet of liquor discharged at the mill per day, b, the amount of water changed per day by tidal action, and V, the total volume of the bay, then

$$\frac{V-a-b}{V} \text{-------------------------------} (1)$$

represents the proportion of original water left at the end of the first day, and

$$\left(\frac{V-a-b}{V}\right)^t \text{-------------------------------} (2)$$

that left at the end of t days. Since

$$\left(\frac{V-a-b}{V}\right)^t = \left(1-\frac{a+b}{V}\right)^t,$$

therefore the proportion of pulp liquor plus the amount of new water is

$$1-\left(1-\frac{a+b}{V}\right)^t \text{---------------------------} (3)$$

Since the amount of pulp liquor in the bay bears the constant ratio of

$$\frac{a}{a+b} \text{------------------------------} (4)$$

to the value of pulp liquor plus new water, therefore the proportion of pulp liquor (p) to the total volume of the bay may be expresses as

$$p=\frac{a}{a+b}\left[1-\left(1-\frac{a+b}{V}\right)^t\right] \text{----------------------} (5)$$

NOTE.—The writer wishes to acknowledge the assistance of Prof. Harold Hotelling of Stanford University in mathmatical problems considered above.

The assumptions made in the derivation of this formula are the source of a small error, but do not rob the results of their significance. In this case it is assumed that the liquor mixed instantaneously and completely with the water and that the inflow of both liquor and water is a continuous process rather than a discontinuous one. Over a long period of time the error due to these two assumptions is negligible although for a period of one or two days the error may be significant. Any error due to lack of mixing of the pulp liquor with the water would tend to increase the amount of liquor in the bay.

By the use of equation 5, the increase in concentration of liquor in Oakland Bay has been calculated, assuming that 70,000 gallons of liquor per day were discharged at the mill. (Table 10.) At first the concentration rises rapidly but at a constantly decreasing rate as equilibrium is approached. As the time factor increases the value of expression (5) approaches the value (4) which expresses the equilibrium concentration, being in this case 1 part of liquor to 931 parts of sea water.

CONCLUSIONS

The effect of sulphite liquor in various dilutions upon oysters is not within the scope of field observations. From data herein given it is concluded that any sulphite waste liquor dumped into Oakland Bay at the Rainier Pulp & Paper Co. plant of necessity must reach the oyster beds. From the physical character of the liquor and from observations, it is apparent that when concentrated liquor is discharged at the mill the accumulation over the oyster beds is greatest near the bottom. Due to the variety of currents the water above the bottom is not comparable to that in which the oysters live, and examinations of water taken at arbitrary locations about the bay can not indicate the conditions with which the oysters must contend. Chemical analysis of the water is not a complete index to the concentration of sulphite waste liquor because the chemical nature of the substances contained therein is unknown. The "oxygen balance" test for the detection of sulphite liquor can not be considered in this problem because no work has ever shown either that the toxicity of sulphite liquor to oysters is in any way proportional to its oxygen demand or that such liquor may not exist unchanged in a toxic state in the presence of dissolved oxygen.

From these facts the following conclusions are drawn:

(1) Conditions in Oakland Bay are unique in the history of oyster culture in Puget Sound. The adult oysters have experienced an abnormally high death-rate for some time, the living oysters spawn little if any, and no set has been obtained in three years.

(2) Other animals, clams, barnacles, mussels, and hydroids, and at least one marine plant, *Melosira borreri*, living on the oyster beds, have been affected in a peculiar manner. Boats, scows, and other floating equipment which have never left the vicinity of the oyster beds do not become covered with barnacles, mussels, and hydroids, which grow upon such equipment under normal conditions. These animals thrive under a wide range of physical conditions, and their absence can not be explained by abnormal temperature or salinity of the water.

(3) There is no evidence by which sewage, log storage, or sawdust could be reasonably considered as an agent of destruction.

(4) The diatom, *Melosira borreri*, normally found in small amounts on oyster beds throughout the lower end of Puget Sound, has changed the character of its growth in Oakland Bay. Apparently this plant is able to use to advantage the chemicals now found in abnormal concentrations in the waters of Oakland Bay. Dense masses of it grow in places where the current is slow, but the area upon which it is found is not the place of highest mortality of the oysters. Some beds which contain the greatest percentage of living oysters have been continually covered with masses of *Melosira*.

(5) Sulphite waste liquor reaches the oyster beds. Its characteristic color has been constantly present in the water over the oyster beds since the mill started operations.

(6) Since the chemical nature of lignin is unknown and since its oxidation products are likewise obscure, no chemical means can be relied upon to demonstrate its presence or absence, in contradiction to visual evidence and observations on the currents.

(7) The "oxygen balance" test is only a measure of stability of dissolved materials, therefore the oxygen demand of any dilution of sulphite liquor is not a reliable index to its toxicity to oysters.

(8) Due to the configuration of Oakland Bay and adjoining bodies of salt water, a small proportion of polluted water escaped each day, and continuous dumping of liquor at the mill gradually builds up a high concentration in the bay.

(9) The dumping of 70,000 gallons of sulphite liquor daily would build up a concentration of 1 part liquor to 931 of water in Oakland Bay. Hopkins has shown (see accompanying report) that the important abnormal conditions of the oysters in Oakland Bay can be reproduced under controlled conditions in the laboratory by subjecting oysters to treatment by mixtures of liquor and sea water of the same strength as shown to be present in Oakland Bay.

Increase in concentration of sulphite liquor in Oakland Bay caused by discharge of 70,000 gallons per day at the mill, calculated from formula 5

Number of days	Parts sea water per 1 part liquor	Number of days	Parts sea water per 1 part liquor
1	102, 940	200	1, 183
10	12, 596	250	1, 086
50	2, 905	300	1, 033
100	1, 730	350	1, 002
150	1, 356	∞	931

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STATISTICAL REVIEW OF THE ALASKA SALMON FISHERIES PART III: PRINCE WILLIAM SOUND, COPPER RIVER AND BERING RIVER[1]

By Willis H. Rich, Ph. D., *Professor of Zoology, Stanford University,* and Edward M. Ball *Assistant, Alaska Service*

CONTENTS

INTRODUCTION

This paper continues the series of reports dealing with the statistics of the salmon fisheries of Alaska. For the sake of uniformity with Parts I and II[2] the policy has been continued of treating only the data up to and including 1927 in spite of the fact that data for three more years are now available. After the data for the remainder of Alaska have been presented in this manner it is planned to supplement these records from time to time with those which have accumulated in the interval and thus to provide statistics as complete as possible for the salmon fisheries of Alaska.

The character of the data and the methods of treatment have been fully described and discussed in the earlier numbers of the series and need not be repeated here.

PRINCE WILLIAM SOUND

Prince William Sound is the largest indentation on the southern coast of Alaska between Cook Inlet and Cross Sound. As here considered, it includes all waters from Cape Fairfield on the west to Point Whitshed on the east. This area is shown

[1] Approved for publication, June 18, 1931.

[2] Statistical Review of the Alaska Salmon Fisheries. Part I: Bristol Bay and the Alaska Peninsula. By Willis H. Rich and Edward M. Ball. Bulletin, U. S. Bureau of Fisheries, Vol. XLIV, 1928 (1929). Bureau of Fisheries Document No. 1041, pp. 41–95, 20 figs. Washington.

Ibid.—Part II: Chignik to Resurrection Bay. Bulletin, U. S. Bureau of Fisheries, Vol. XLVI, 1930 (1931). Bureau of Fisheries Document No. 1102, pp. 643–712, 11 figs. Washington.

in the maps, Figures 1 to 3. Its shore line is very irregular, as several deep, narrow fiords or bays in the western and northern parts extend inland to the active glaciers which fill the valleys of the coast range of mountains. The eastern part of the sound also has numerous bays, but none is touched directly by glaciers, although some of the streams are discolored by glacial water from the ice fields a few miles back from the coast, as in the Valdez Arm section. Although beach areas are very limited in the eastern bays, the shores are less precipitous. For the most part, the streams in the eastern section are clear and flow over gravel bottoms through small valleys and meadowlands and provide excellent spawning grounds for salmon. No large rivers are tributary to any part of the sound. The lakes of the region are also small and few in number, while the streams are short, not more than a few miles in length at

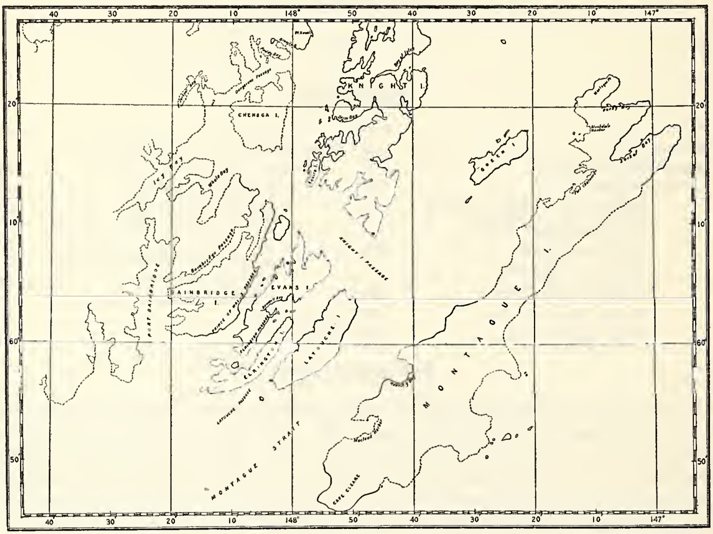

FIGURE 1.—Map of the southwestern part of Prince William Sound

most. Conditions, therefore, are not favorable for red salmon though a few streams produce small runs of this species, notably Eshamy, Miners River, Coghill River, Billys Hole, Jackpot Bay, and Port Valdez, all but one of which are located in the western section. The sound is predominantly a pink-salmon district, although fair catches of chums have been made in late years.

In early years, fishing records were not kept with a view of showing precisely the locality in which catches were made, so information that would now be useful in this review is not obtainable. For that reason errors in the allocation of these early catches have been unavoidable—errors that can not be corrected. In later years, catch records were more carefully kept, and many of the defects of the past were largely eliminated.

The earliest recorded commercial catch of salmon in Prince William Sound was made in 1893. It is probable, however, that salmon were taken here commercially as early as 1889, when the first cannery was operated on the Copper River where red and king salmon were the predominant species and the only ones having at that time a commercial value. Due to the fact that the runs in the Copper River come early and are of short duration, an opportunity was afforded for the exploration of the sound, and it is probable that the red-salmon streams already named were discovered and fished a few weeks each season; not so much for the catches that might be made but to give the men who had been employed as fishermen on Copper River a few more weeks' work while the pack from that district was being prepared for

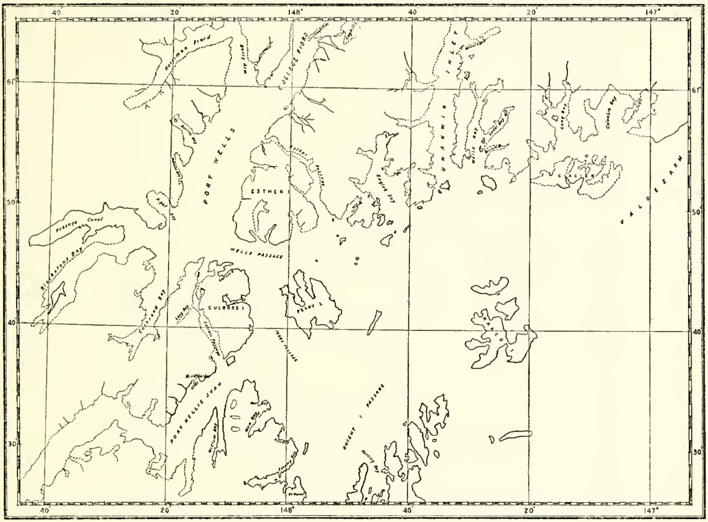

FIGURE 2.—Map of the northwestern part of Prince William Sound

shipment. If such catches were made before 1893, they were probably packed as Copper River salmon and so reported.

The first canneries to pack salmon definitely taken from Prince William Sound were built in 1889 at Odiak—a site between Eyak Lake and the present town of Cordova which was settled about 20 years later during the construction of the Copper River & Northwestern Railway. From that year until 1898, a period of nine years, it might be supposed that the sound had been completely explored and that the salmon packers could then make a fairly close estimate of the salmon resources of the region. However, Moser,[3] referring to Prince William Sound, reported in 1898 that "the cannery people are constantly striving to increase their packs, the steamers have prospected the locality very thoroughly, and it is believed that all the salmon streams

[3] The Salmon and Salmon Fisheries of Alaska, by Jefferson F. Moser. Bulletin, U. S. Fish Commission, Vol. XVIII, 1898 (1899), pp. 1-178. Washington.

of any value are known. The runs of fish are very uncertain, and as they vary largely from year to year, data of material value can not be obtained." He also says that "Except Cheniga, the streams are all said to have small runs, and the pack of Prince William Sound fish is small." In the same report, he states "The salmon streams of Prince William Sound resemble those of southeast Alaska, although as a rule they are inferior. The total catch for the whole district does not equal the catch of such streams as Quadra, Hetta, and others in a good season, and probably does not average

FIGURE 3.—Map of the eastern part of Prince William Sound

over 125,000 redfish and 50,000 cohos per season. The Pacific Steam Whaling Co.'s cannery has never exceeded 32,000 redfish and 35,000 cohos per season from the sound. While there are many streams that contain humpbacks, they are not very plentiful in any one stream. In none do they run even as they do in the smaller streams of southeast Alaska, and they, as well as the redfish and cohos, are decreasing yearly. In short, the district is poor in salmon, and the streams have been injured by injudicious and illegal fishing."

Subsequent developments have demonstrated the fallacy of Moser's conclusions, for, instead of being exhausted, the fisheries had hardly been touched, as is fully shown in the history of salmon canning on Prince William Sound in later years. From 1897 to 1904, the number of canneries taking salmon from the sound was never more than 2, and in the next 10 years only 1 was in operation. There was no unusual variation in the catch from year to year, and no evidence that the runs were being destroyed by intensive fishing. After 1914, however, important changes in the intensity of fishing began, due to the establishment of other canneries in the district, all of which entered this field to exploit the pink salmon fisheries. The character of fishing changed from gill nets and beach seines to a preponderant use of purse seines and traps. The catch increased proportionately with the increase of canneries and fishing appliances until 1920, when 15 canneries, operating 54 beach seines, 63 purse seines, 217 gill nets, and 47 traps were taking salmon from Prince William Sound.

There is no such definite distinction between the salmon catches in different sections of Prince William Sound as exists between many of the fishing areas to the westward. In various districts that have been treated in Parts I and II the fishery draws upon the salmon produced by only one, or, at most, a few streams, and the catches made can be referred with considerable accuracy to the streams in which the fish originated. This can not satisfactorily be done in such a district as Prince William Sound where many of the important fishing operations are conducted in regions where fish are merely passing through and from which they disperse widely to spawning grounds in all parts of the sound. As will be shown later, similar conditions exist in southeastern Alaska and the same, even greater, difficulties are encountered there in attempting to analyze the statistics. In certain well-defined and limited areas in Prince William Sound catches have been reported that unquestionably are properly allocated to the area in question, but this does not measure the total draft upon the salmon runs native to the area since the fisheries located in the channels through which the fish have passed have taken toll of the runs to an unknown extent. However, it has seemed best to preserve the data in as great detail as possible in spite of their deficiencies, and the table, therefore, gives the data for each definite geographic unit from which catches have been consistently reported.

In addition the sound has been divided into 10 subdivisions, and data are given separately by localities for each one, with the final section of the table for each division showing the total catch in that particular area. The sound is also divided into two parts—eastern and western—the line of separation extending from Point Freemantle on the north to Montague Point on the south. The subdivisions are considered from west to east, and a section of the table immediately following the tabulation of catches in the six districts of the western part shows the total catch in the western part of the sound. Data for the eastern part are presented in the same way, while the last division of the table gives the total catch of salmon by species and the number of fishing appliances used in Prince William Sound. These statistics are given in Table 1.

A considerable part of the catch in many years was simply reported as coming from Prince William Sound without reference to any of the bays or inlets. It was impossible to allocate these catches to specific waters but a more or less arbitrary allocation has been made between the eastern and western parts of the sound. Furthermore, small catches were made occasionally in known localities which were not of sufficient importance to be shown separately; these were put in with the unallocated catches. Other catches were made at places merely designated as Knight Island, Montague Island, and the like, without mention of the waters from which

they were taken. Certain combinations of catches have also been made, as where one locality is known by different names, or where several small localities are contained wholly within a larger body of water, such as Port Wells, Port Fidalgo, and so on. These combinations of unallocated catches will be discussed in detail in the sections dealing with the particular localities.

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Knight Island Passage district:												*Number*
Bainbridge Passage—												
1913			16		110							
1917			24,191		105							
1918		5,040	79,443		1,696							
1919	260	764	6,872	97	1,075							
1920			1,945									
1925	184	73	5,367	15	166							
1926			860									
1927	1,565	322	470									
Chenega Creek and Chenega Island—												
1918	2,099	8,527	112,542	62	18,551							
1919	434	1,341	18,084	42	3,260							
1920	1,126	2,861	157,705	107	4,697							
1921	350	1,000	10,000		8,600							
1922	126	1,950	221,802		3,166							
1923	6	120	88,065	3	610							
1924	166	1,868	276,050		4,756							
1925	184	4,482	137,086		8,235							
1926	1,260	6,085	419,668		28,124							
1927	1,221	5,999	412,498		14,406							
Drier Bay—												
1913			518		2							
1918			2,000									
1919			15,266									
1920		254	11,629		15							
1924		1,385	119,678									
1925		102	2,469									
1926		1,141	48,133		240							
1927	1	1,341	41,044		117							
Eshamy Bay and Lagoon—												
1904				28	54,000							
1905					100,000							
1906					57,862							
1907					17,692							
1908					117,018							
1909					136,603							
1910					63,710							
1911					5,292							
1912	841		3,666		15,207							
1913	383		6,049	3	56,554							
1914	3		7,270		50,305							
1915			10,819		24,386							
1916		417	36,167	6	15,913							
1917	86	4,870	77,065	43	98,196							
1918	1,993	1,223	39,832	32	103,586							
1919	1,220	5,946	27,308	19	52,296							
1920	1,663	952	33,591	64	20,628							
1921	169	375	444		50,335							
1922	868	7,590	370,006	24	92,594							
1923	2,800	221	68,932	22	116,167							
1924	491	309	14,085		2,470							
1925	13	969	4,086		4,497							
1926		1,245	32,693									
1927	352	1,781	22,844	11	15,118							
Falls Bay—												
1922			2,321	10	2,975							
1924	14	1,195	15,205		1,470							
1925	112	3,755	6,561		8,226							
1926		534	5,922		7,850							
1927	75	444	4,086	3	12,320							
Granite Bay—												
1918			6		20							
1924	20	2,345	21,183	3	2,920							
1925	200	4,773	82,581		4,055							
1926	85	595	6,213		8,208							
1927	235	1,776	43,626		13,559							
Jackpot Bay—												
1911					5,885							
1912	150		3,760		3,000							
1913			950		3,091							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Knight Island Passage district—Continued.												*Number*
Jackpot Bay—Con.												
1914					1,977							
1917	19	4,391	9,599	6	21,770							
1918	920		15,000		5,500							
1919		4,843	15,381		3,408							
1920		67	6,967		80							
Latouche Passage—												
1919	46											
1925	794	191	3,749	20	322							
1927	1,945	3	105,643		486							
Main Bay—												
1920		12	14,756									
1924	10	891	12,445		1,450							
1926		450	6,310		7,960							
1927	80	448	4,219		12,926							
Nowell, Point—												
1917	6	131	607	1	9,190							
1925	182	1,773	1,929		2,748							
1927	14	120	14,943		1,923							
Prince of Wales Passage—												
1919	427	383	9,312		10,368							
1920	465	537	19,036	53	1,115							
1921					600							
1922	20				1,708							
1923					2,148							
1924	334	577	46,185		92							
1926	921	2,174	95,763	71	4,264							
Squire Island—												
1926	130	660	69,160		638							
1927	302	363	70,043		749							
Thumb Bay—												
1926		56	27 042		40							
1927	2	219	8,756		6							
Whale Bay—												
1918		3,000	2,000									
1920		110	465									
1926		1,225	36,553		10							
Unallocated—												
1913			758		67							
1917		8,822	17,883									
1918	50	3,243	4,310	2	3,236							
1919	1,329	1,375	11,447	7	14,714							
1920	612	1,525	65,430	30	8,493							
1923					2,366							
1925		1,476	47,424		7							
1926		531	47,120		3							
1927	4	95	3,862		343							
Total—												
1904				28	54,000							
1905					100,000							
1906					57,862							
1907					17,692							
1908					117,018							
1909					136,603							
1910					63,710							
1911					11,177							
1912	991		7,426		18,207							
1913	383		8,291	3	59,824							
1914	3		7,270		52,282							
1915			10,819		24,386							
1916		417	36,167	6	15,913							
1917	111	18,214	129,345	50	129,261							
1918	5,062	21,033	255,133	96	132,589							
1919	3,716	14,652	103,670	165	85,121							
1920	3,866	6,318	311,524	254	35,028							
1921	519	1,375	10,444		59,535							
1922	1,014	9,540	594,129	34	100,443							
1923	2,806	341	156,997	25	121,291							
1924	1,035	8,570	504,831	3	13,158							
1925	1,669	17,594	291,252	35	28,256							
1926	2,396	14,696	795,437	71	57,337							
1927	5,796	12,911	732,034	14	71,953							
Montague Strait district:												
Bay of Isles—												
1912	600		1,600		2,500							
1913	23		2,006		1,436							
1917	6	2,754	8,252		4,307							
1918	7	622	22,531		3,506							
1919			1,519		651							
1920	412		12,339		1,040							
1922		30			347							
1926		959	9,166		34							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Montague Strait district—Continued.												*Number*
Cleare, Cape—												
1926		475	23,109		22							
1927	9,463	412	52,566	935	777							
Chalmers, Port—												
1917	724		5,088									
1918	831	22,468	20,215		19							
1924	11	4,739	31									
1925	11	9,626	179,464		8							
1926	1,318	26,618	70,620		142							
1927	5,315	24,647	157,573		11							
Glacier Bay—												
1926	2,521	4,056	137,169	105	2,858							
1927	3,759	2,508	96,810	66	363							
Hanning Bay—												
1920	1,617	1,117	28,731	208	355							
1924			1,040									
1925	5,350	1,326	26,481	265	1,271							
1926	2,804	5,377	135,480	134	3,273							
1927	3,743	4,281	115,429	329	1,281							
Macleod Harbor—												
1918			1,500									
1920	35,766	12,852	249,500	3,361	7,947							
1924	34,379	16,562	800,167	1,000	10,665							
1925	33,352	9,463	115,531	1,206	10,746							
1926	16,713	22,002	581,248	1,104	22,545							
1927	27,535	15,024	338,141	1,143	6,191							
Stockdale Harbor—												
1917			8,785		1							
1925		2	4,597									
1926			10,135									
Unallocated—												
1917			12,231		595							
1919	51	836	680		130							
1925			1,377									
1926		1,178	32,564									
1927	4,732	20,042	71,336	13	262							
Total—												
1912	600		1,600		2,500							
1913	23		2,006		1,436							
1917	730	2,754	34,356		4,903							
1918	838	23,090	44,246		3,525							
1919	51	836	2,199		781							
1920	37,795	13,969	290,570	3,569	9,342							
1922		30			347							
1924	34,390	21,301	801,238	1,000	10,665							
1925	38,713	20,417	327,450	1,471	12,025							
1926	23,356	60,665	999,491	1,343	28,874							
1927	54,547	66,914	831,855	2,486	8,885							
Port Wells district:												
Bettles Bay—												
1917		900	2,804		4							
1918	152	3,003	114,950	1	1,550							
1919		86	304		1							
1920	160	19	15,498	4	5							
1924		258	519		5							
1925		1,305	1,224									
1926		1,542	30,465									
1927		1,460	13,000									
Cochrane Bay—												
1918		16	15,587		60							
1919		403	4,206		6							
1920	157	1,769	232,105	1	75							
1924	8	7,580	440,781		4,395							
1925		13,762	35,426									
1926		15,218	312,814		400							
1927	54	12,750	146,728		655							
Coghill River—												
1914					3,533							
1917	2	20	911	20	23,448							
1918	249	4,463	23,692	11	31,994							
1919	356	3,637	20,999	11	7,558							
1920	21	421	3,206	16	3,944							
1924		730	2,450		7,788							
1926		1,356	32,019									
1927		1,260	16,500									
Culross Passage—												
1917		19,988	17,004		37							
1918	1	32,599	59,577		163							
1919	242	9,905	38,301		777							
1920	53	2,338	28,397		5							
1922			3,036									
1924		4,110	199,924		607							
1925	69	19,404	204,329		154							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Port Wells district—Con.												
Culross Passage—Continued.												*Number*
1926	-	14,557	380,681	-	400	-	-	-	-	-	-	-
1927	52	12,197	261,410	1	627	-	-	-	-	-	-	-
Culross, Point—												
1926	-	1,606	84,490			-	-	-	-	-	-	-
1927	-	560	89,570	2	32	-	-	-	-	-	-	-
Esther Passage—												
1914	-	-	-	-	1,003	-	-	-	-	-	-	-
1918	37	1,596	78,191	10	2,126	-	-	-	-	-	-	-
1919	25	871	8,204	96	1,041	-	-	-	-	-	-	-
1920	6	19	4,875	5	242	-	-	-	-	-	-	-
1922	-	-	-	-	215	-	-	-	-	-	-	-
1924	-	-	-	-	473	-	-	-	-	-	-	-
1925	12	1,767	22,301	-	1,990	-	-	-	-	-	-	-
1926	-	468	6,806	-	604	-	-	-	-	-	-	-
Hummer Bay—												
1918	-	2,284	21,149	-	-	-	-	-	-	-	-	-
1920	21	114	14,586	1	18	-	-	-	-	-	-	-
1924	-	152	71,071	-	103	-	-	-	-	-	-	-
1925	-	7,110	56,519	-	38	-	-	-	-	-	-	-
1926	-	1,284	109,134	-	-	-	-	-	-	-	-	-
1927	-	1,190	40,700	-	-	-	-	-	-	-	-	-
Long Bay—												
1917	1	752	26,842	-	73	-	-	-	-	-	-	-
1919	-	1,128	1,060	-	2	-	-	-	-	-	-	-
1920	-	235	3,571	-	20	-	-	-	-	-	-	-
1924	-	-	26,978	-	-	-	-	-	-	-	-	-
1926	-	3,845	37,227	-	-	-	-	-	-	-	-	-
1927	-	1,092	14,845	-	-	-	-	-	-	-	-	-
McClure Bay—												
1917	-	9,002	5,148	9	12	-	-	-	-	-	-	-
1918	-	7,728	12,084	-	3	-	-	-	-	-	-	-
1919	6	4,746	7,594	2	663	-	-	-	-	-	-	-
1920	207	1,389	14,612	13	9	-	-	-	-	-	-	-
1925	-	8,123	3,826	-	-	-	-	-	-	-	-	-
Mink Harbor—												
1918	1	2,352	7,806	-	1	-	-	-	-	-	-	-
1924	-	3,959	268,748	-	47	-	-	-	-	-	-	-
1925	-	6,059	120,379	-	-	-	-	-	-	-	-	-
1926	-	16,540	340,015	-	408	-	-	-	-	-	-	-
1927	59	13,860	159,438	-	710	-	-	-	-	-	-	-
Nellie Juan, Port—												
1917	3	31,648	23,730	-	-	-	-	-	-	-	-	-
1918	23	53,956	165,840	-	71	-	-	-	-	-	-	-
1919	6	16,694	20,365	-	271	-	-	-	-	-	-	-
1920	251	14,870	379,657	-	114	-	-	-	-	-	-	-
1924	-	14,115	534,546	-	2	-	-	-	-	-	-	-
1925	24	29,476	44,020	-	33	-	-	-	-	-	-	-
1926	-	1,460	213,737	-	392	-	-	-	-	-	-	-
1927	-	1,350	15,000	-	229	-	-	-	-	-	-	-
Pigot Bay—												
1918	2	1,578	30,925	-	8	-	-	-	-	-	-	-
1919	-	40	1,143	-	-	-	-	-	-	-	-	-
1920	21	822	54,106	2	23	-	-	-	-	-	-	-
1924	-	3,413	27,813	-	1,645	-	-	-	-	-	-	-
1925	-	14,284	22,713	-	-	-	-	-	-	-	-	-
1926	-	1,526	31,463	-	-	-	-	-	-	-	-	-
1927	74	2,113	53,162	-	112	-	-	-	-	-	-	-
Wells, Port—												
1912	-	-	-	-	6,333	-	-	-	-	-	-	-
1913	-	-	-	-	2,257	-	-	-	-	-	-	-
1917	-	-	8,000	-	-	-	-	-	-	-	-	-
1918	10	5,332	220,024	-	730	-	-	-	-	-	-	-
1919	92	23,230	52,294	11	3,383	-	-	-	-	-	-	-
1920	223	4,062	356,693	30	2,206	-	-	-	-	-	-	-
1921	-	-	-	-	6,749	-	-	-	-	-	-	-
1922	-	310	478,551	-	74	-	-	-	-	-	-	-
1923	-	-	59,000	-	-	-	-	-	-	-	-	-
1924	110	6,254	328,470	6	7,112	-	-	-	-	-	-	-
1925	504	10,345	107,732	-	9,962	-	-	-	-	-	-	-
1926	-	1,489	36,800	-	61	-	-	-	-	-	-	-
1927	2	2,313	143,461	-	412	-	-	-	-	-	-	-
Total—												
1912	-	-	-	-	6,333	-	-	-	-	-	-	-
1913	-	-	-	-	2,257	-	-	-	-	-	-	-
1914	-	-	-	-	4,536	-	-	-	-	-	-	-
1917	6	62,310	84,439	29	23,574	-	-	-	-	-	-	-
1918	475	114,907	749,825	22	36,706	-	-	-	-	-	-	-
1919	727	60,740	154,470	120	13,702	-	-	-	-	-	-	-
1920	1,120	26,058	1,107,306	72	6,661	-	-	-	-	-	-	-
1921	-	-	-	-	6,749	-	-	-	-	-	-	-
1922	-	310	481,587	-	289	-	-	-	-	-	-	-
1923	-	-	59,000	-	-	-	-	-	-	-	-	-

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Port Wells district—Con.												*Number*
Total—Continued.												
1924	118	40,571	1,901,300	6	22,177							
1925	609	111,635	618,469		12,177							
1926		60,891	1,615,651		2,265							
1927	241	50,145	953,814	3	2,777							
Eaglek Bay district:												
Eaglek Bay—												
1917	2	14,294	46,605	3	112							
1918		28,450	77,903		390							
1919	99	11,024	13,613	1	61							
1920	6	43	10,987	2	17							
1922		972	4,105									
1923			1,511		1,109							
1924		4,361	1,260		168							
1925		41,690	3,342									
1926		1,755	35,298		886							
1927		1,575	15,500									
Unakwik Inlet district:												
Cedar Bay—												
1916					95							
1917		6,911	17,955	2	955							
1918		6,848	145,530		8							
1919	200	10,141	9,876									
1920	818	1,914	44,001	3	503							
1922			6,544		14							
1924			13,274									
1926		45	29,611		96							
1927		2,473	2,859		264							
Granite Point—												
1926	428	3,117	167,934		2,914							
1927	348	1,445	76,057		1,510							
Miners River—												
1904				125	4,000							
1906					1,854							
1909					13,290							
1910					3,150							
1911					6,591							
1912			4,794		11,435							
1913					8,517							
1914					6,180							
1915					6,771							
1916			604		6,524							
1917					3,056							
1918					11,989							
1919					4,808							
1921					8,361							
1922					1,421							
1923		1	279		1,165							
Unakwik Inlet—												
1917			9,062		124							
1919		6,560	7,821		3,208							
1922		240	104,140		2,775							
1923		1,501	88,134		1,042							
1924	155	980	872,777		4,149							
1925	252	29,181	427,759		5,871							
1926	299	26,379	1,435,857	22	5,151							
1927		17,209	392,652		1,658							
Wells Bay—												
1917		4,250	133,388		58							
1918	68	40,415	29,988		252							
1919		19,023	10,723		255							
1920		5,826	31,422		459							
1922		2,634	22,590		114							
1923			1,000									
1924		198										
1925		3,098	26,854									
1926		2,211	24,654		1							
1927		3,025	16,993									
Total—												
1904				125	4,000							
1906					1,854							
1909					13,290							
1910					3,150							
1911					6,591							
1912			4,794		11,435							
1913					8,517							
1914					6,180							
1915					6,771							
1916			604		6,619							
1917		11,161	160,405	2	4,193							
1918	68	47,263	175,518		12,249							
1919	200	35,724	28,420		8,271							
1920	818	7,740	75,423	3	962							
1921					8,361							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unakwik Inlet district—Continued.												
Total—Continued.												*Number*
1922		2,874	133,274		4,324							
1923		1,502	89,413		2,207							
1924	155	1,178	886,051		4,149							
1925	252	32,279	454,613		5,871							
1926	727	31,752	1,658,056	22	8,162							
1927	348	24,152	488,561		3,432							
Glacier Island district:												
Billys Hole—												
1904				100	3,000							
1906					862							
1909					519							
1910					1,262							
1911					5,362							
1912			1,880		7,470							
1913					3,249							
1914					9,350							
1915					15,775							
1916		200	32,199		10,908							
1917		6,737	61,819		5,187							
1918		19,392	12,209		4,196							
1919		8,161	13,067		2,964							
1920		3,279	54,871		2,244							
1921					3,234							
1922			1,381		1,964							
1923		254	6,250		3,210							
1927			24		109							
Long Bay—												
1917			2,500									
1922		2,950	187,459		2,381							
1923		679	82,283		3,234							
1924		675	36,846		3,005							
1925		8,881	101,193		897							
1926		4,687	168,904		358							
1927	22	14,323	69,335		2,974							
Unallocated—												
1917	372		9,887		1,390							
1922	16		4,769		3,560							
1927	1	7,963	39,581		31							
Total—												
1904				100	3,000							
1906					862							
1909					519							
1910					1,262							
1911					5,362							
1912			1,880		7,470							
1913					3,249							
1914					9,350							
1915					15,775							
1916		200	32,199		10,908							
1917	372	6,737	74,206		6,577							
1918		19,392	12,209		4,196							
1919		8,161	13,067		2,964							
1920		3,279	54,871		2,244							
1921					3,234							
1922	16	2,950	193,609		7,905							
1923		933	88,533		6,444							
1924		675	36,846		3,005							
1925		8,881	101,193		897							
1926		4,687	168,904		358							
1927	23	22,286	108,940		3,114							
Unallocated, western part:												
1904					[1] 48,200							
1913				500								
1915					3,680							
1916			232,000		16,881							
1917	1,838	184	93,000		17,576							
1918	11,841	33,555	192,479		12,683							
1919	11,203	24,242	76,778	4,875	5,955							
1920	8,743	22,622	806,537	287	22,292							
1922			38,702		4,784							
1923	5,792	33,032	611,661		4,024							
1924	275	25	14,057									
1925	2,151	1,172	49,628	81	1,013							
1926		121	17		21,213							
Total, western part:												
1904				253	109,200							
1905					100,000							
1906					60,578							
1907					17,692							

[1] Probably from Eshamy Lagoon and/or Chenega Creek.

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Total, western part—Continued.												*Number*
1908					117,018							
1909					150,412							
1910					68,122							
1911					23,130							
1912	1,591		15,700		45,945							
1913	406		10,297	503	75,283							1
1914	3		7,270		72,348							
1915			10,819		50,612							
1916		617	300,970	6	50,321							
1917	3,059	115,654	622,356	84	186,196							
1918	18,284	287,690	1,507,313	118	202,338							3
1919	15,996	155,379	392,217	5,161	116,855							17
1920	52,348	80,029	2,657,218	4,187	76,546							20
1921	519	1,375	10,444		77,879							1
1922	1,030	16,676	1,445,406	34	118,092							3
1923	8,598	35,808	1,007,115	25	135,075							4
1924	35,973	76,681	4,145,583	1,009	53,322							12
1925	43,394	233,668	1,845,947	1,587	60,239							15
1926	26,479	174,567	5,272,854	1,436	119,095							21
1927	60,955	177,983	3,130,704	2,503	90,161							35
Valdez Arm district:												
Bligh Island—												
1926	1,107	19,699	288,802	57	1,420							
1927	1,236	8,985	50,375	22	414							
Galena Bay—												
1917	1,061	43,310	191,653	8	476							
1918	617	108,352	136,222		11							
1919	311	28,068	9,898		62							
1920	6	10,740	120,418		1							
1923		13,515	23,725									
1924		19,312	224,258									
1925	98	93,868	113,306		12							
1926	3	52,576	218,281	6	118							
1927	1	31,738	71,271		30							
Jack Bay—												
1917		5,047	46,847		109							
1918		14,391	28,242		54							
1919		9,617	8,749		26							
1920	285	8,094	99,772		112							
1923		1,068	21,871									
1924		2,478	130,972		14							
1925		10,144	56,713		46							
1926	1,046	51,420	392,931		449							
1927	163	59,252	145,290	11	1,169							
Lowe Point—												
1920	270	6,080	117,500	59	2,627							
1927	169	731	2,360	7	234							
Potato Point—												
1920	900	7,974	135,000	50	2,855							
1922	1,302	14,048	226,244	252	5,896							
1925	1,149	20,318	47,515	25	1,612							
1926	312	10,035	174,750	17	2,340							
Sawmill Bay—												
1917		7,424	39,654		62							
1918		56,548	43,760	4	7							
1919		30,240	25,852		289							
1920	293	8,919	113,191	63	2,636							
1923			20,220									
1924		40	5,532									
1925	1,381	18,676	51,772	17	1,265							
1926	336	10,974	144,859	24	2,051							
1927	2	1,495	70,102		11							
Valdez Arm—												
1917	1,144	787		33								
1920	128	2,938	16,531	11	9,278							
1923	462	4,216	65,308	447	5,205							
1924	104	4,237	227,811		2,683							
1925	1,377	547	860									
1926	657	5,051	128,632		994							
1927	1,017	9,695	39,751	5	223							
Valdez, Port—												
1917	8,167	1,511	517		19,012							
1918	14,616	13,414	14,307	6	18,088							
1919	10,601	20,265	15,684		18,405							
1921	2,406	2,124			14,692							
1922			11,173		10,911							
1923		566	148	4	15,548							
1924	1,153	39,480	434,122	180	10,211							
1925	2,879	6,760	3,485	8	9,084							
1926	695	6,935	6,043		4,861							
1927	1	2,213	5,525	1	9,086							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Valdez Arm district—Continued.												*Number*
Total—												
1917	10,372	58,079	278,671	41	19,659							
1918	15,233	192,705	222,531	10	18,160							
1919	10,912	88,190	60,183		18,782							
1920	1,882	44,745	602,412	183	17,509							
1921	2,406	2,124			14,692							
1922	1,302	14,048	237,417	262	16,807							
1923	462	19,365	131,272	451	20,753							
1924	1,257	65,547	1,022,695	180	12,908							
1925	6,884	150,313	273,651	50	12,019							
1926	4,156	156,690	1,354,298	104	12,233							
1927	2,589	114,109	384,674	46	11,167							
Port Fidalgo district:												
Bidarka Point—												
1919		5,699	12,119									
1920		11,662	142,558	64	3,768							
1925	3,864	16,721	65,631	29	2,945							
1926	677	12,744	221,361	19	2,436							
1927	1,842	8,619	120,886	59	2,277							
Fidalgo, Port—												
1913			120,653									
1914			46,663									
1915	5,375											
1916			81,991									
1917	2,442	63,365	166,657	183	214							
1918	8,160	146,243	192,090	12	358							
1919	4,177	10,323	8,789	16	170							
1920	86	15,120	14,737		25							
1924	1,550	21,565	8,332									
1925	177	3,401	11,540	91	408							
1926	1,715	18,932	451,570	1	754							
1927	6,220	44,412	189,715	14	662							
Fish Bay—												
1914			77,046									
1915			35,312									
1917	900	4,369	41,495		11							
1918		22,568	56,558		11							
1919		7,072	980		186							
1922			9,730									
1923		7,793	57,666		108							
1924		10,299	1,664									
1925	240	47,659	61,465		41							
1926		37,913	25,364	1	129							
1927		4,248	1,374		5							
Irish Cove—												
1915			11,300									
1917			1,016									
1918		371	23,138		961							
1923		242	23,605									
1925	2,962											
1926	4,198	1,649										
1927	7,066											
Porcupine Point—												
1918	3,461	6,858	201,994	219	4,494							
1919	5,417	9,372	28,718	227	1,808							
1920	3,812	5,359	86,013	232	4,156							
1924	3,000	2,100	210,748		1,550							
1925	3,326	8,200	120,239		2,346							
1926	1,217	3,705	249,212	22	1,426							
1927	2,350	11,303	120,707	64	1,313							
Sunny Bay—												
1919	1,057	19,283	2,988		2							
1923		2,262	9,025									
1924	105	48,854	16,733		149							
1925	179	29,939	17,195		133							
Whalen Bay—												
1915			16,792									
1917		1,078	25,120									
1918		19,814	104,291		800							
1919	342	8,314	3,567		129							
1923		3,095	38,757									
1924		20,531	900									
1925		11,715	37,031		16							
1926		3,839	1,294	1	6							
1927		831	768		1							
Total—												
1913			120,653									
1914			123,709									
1915	5,375		63,404									
1916			81,991									
1917	3,342	68,812	234,288	183	225							
1918	11,621	195,854	578,071	231	6,624							
1919	10,993	60,063	57,161	243	2,295							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Port Fidalgo district—Continued.												*Number*
Total—Continued.												
1920	3,898	32,141	243,308	296	7,949							
1922			9,730									
1923		13,392	129,053		108							
1924	4,655	103,349	238,377		1,699							
1925	10,748	117,635	313,101	120	5,889							
1926	7,807	78,782	948,801	44	4,751							
1927	17,478	69,413	433,450	137	4,258							
Port Gravina and Orca Bay district:												
Anderson Bay—												
1917			12,372									
1918	11	2,309	9,596		6							
1923		294	2,490									
1924	5	26,470	228,777		39							
1925		10,171	50,610		4							
1926	1	8,762	115,250		8							
1927	41,722	31,296	125,690	19	241							
Bear Trap Bay—												
1915			13,725									
1917		2,319	20,000		120							
1923		40	1,962		3							
1925		5,656	9,947	1	264							
1926		210	19,991		12							
1927	70	4,219	8,671		83							
Canoe Passage—												
1911			25,035									
1915			15,837									
1917			12,309									
1918		185	4,483		4							
1924		83	9,809									
1925		1,603	23,234									
1926		1,199	119,591		73							
1927		1,068	2,250		30							
Double Bay—												
1925		869	4,496		1							
1926		3,984	31,714		1							
1927		5,176	10,592									
Gravina Point—												
1918		300	96,300									
1919	2,153	33,955	75,676									
1920	2,352	6,668	70,968	159	1,926							
1922			25,302		228							
1924	575	15,631	895,690		176							
1925	1,839	17,583	147,458	43	616							
1926	66	21,118	468,757	95	1,852							
Gravina, Port—												
1907			132,198									
1908			18,018									
1910	14,411		140,802									
1911	20,284		69,708									
1912	12,706	405	381,219									
1913			206,649									
1914	11,310		40,800									
1915	1,540	2,124	271,170									
1916		2,420	226,176									
1917	9,530	2,588	35,672	3	889							
1918	9,343	75,119	401,049	7	1,177							
1919	11,101	20,263	27,456		701							
1921	5,391											
1923		13	957		616							
1924	12,295	4,541	165,705		1,222							
1925	4,792	6,491	13,855		1,137							
1926	6,810	4,431	146,769	20	688							
1927	31,085	15,723	126,447		863							
Hawkins Cut-off—												
1917				2	116							
1918	1,067	35,485	227,033		91							
1919	403	8,434	8,818									
1920	1,332	3,578	57,401	86	1,119							
1922	20	668	79,153		334							
1924		1,279	19,395									
1925	2,279	33,065	165,605	18	85							
1926	4,230	11,880	304,519		89							
1927	3,291	27,004	197,814	8	326							
Johnstone Point—												
1917	832	396	25,071		5							
1920	2,199	8,853	63,013	159	2,680							
1922			6,072									
1924		12,304	394,431									
1925	1,130	25,828	146,296	27	414							
1926	1,344	23,307	460,527	98	9,458							
1927	1,632	22,464	258,050	24	1,909							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Port Gravina and Orca Bay district—Con.												*Number*
Knowles Head—												
1918	95	1,321	3,202	22	9,826							
1919	7,325	5,643	52,109	190	4,720							
1920	8,236	6,231	96,231	236	4,038							
1922	6,610	19,125	346,248		4,368							
1923	8,667	6,320	213,173	40	10,140							
1924	11,918	4,128	233,972		3,222							
1925	4,657	11,480	169,569		3,094							
1926	2,797	11,103	230,931	85	4,281							
1927	5,949	17,993	157,125	142	2,906							
Makaka Point—												
1915		51	5,545		17							
1917			5,368		309							
1918	53	1,699	9,250		390							
1924	2	213	57,078		25							
1925		1,298	51,479									
1926	39	210	32,105		72							
1927	1,110	15,478	205,463	15	681							
Olsen Bay—												
1918		28,132	79,341									
1919	114	7,082	13,688									
1923		8,353	122,764		275							
1924	116	44,679	193,137	3	708							
1925	408	48,456	47,245	5	600							
1926	52	11,031	189,062	12	119							
1927	20	17,268	38,764		109							
Orca Bay—												
1904			43,795									
1912	208				302							
1916			452,347									
1917	39		9,043									
1922			38,549									
1924		101	156	27	3,122							
1925		2,673	22,594		10							
1926	143	1,517	470,750		166							
1927	781	4,622	49,949		12							
St. Matthew Bay—												
1915			12,524									
1916		352										
1918		1,068	6,437		398							
1920		5,199	36,090	85	899							
1922			19,638									
1923			1,805		18							
1924		12,563	486,984									
1925	811	8,341	43,443	18								
1927	468	8,196	72,280	6	405							
Sheep Bay—												
1910			34,882									
1911			23,467									
1912			4,973									
1913		70	36,017									
1915			3,420									
1916			101,431									
1917		3,519	31,412									
1918		10,342	25,439		71							
1920	1,920	1,768	36,742	62	2,010							
1922			24,317									
1923		249	82,589	11	6							
1924		9,150	84,588		6							
1925	2	30,371	117,768		174							
1926	1	7,023	84,630	13	110							
1927	3,412	32,790	156,080	2	108							
Simpson Bay—												
1907			120,175									
1912	1,058				1,302							
1913			18,365		129							
1914	949											
1915			1,220		179							
1916			18,898									
1917	1,000		40,260		1,286							
1918	1,192	9,376	18,852		340							
1923		647	38,358		22							
1924	2,207	2,683	103,133		356							
1925	2,307	1,577	7,975		55							
1926	2,151	4,507	110,712		1,230							
1927	3,713	6,476	28,415		627							
Windy Bay—												
1910			21,187									
1911			38,139									
1913			27,957									
1914			53,127									
1915			9,187									
1917			7,003									

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Port Gravina and Orca Bay district—Con.												
Windy Bay—Con.												*Number*
1918		3,387	14,228		93							
1922			104,524		547							
1924	428	1,100	53,830		12							
1925		440	10,047									
1926		6,120	88,428		8							
1927	12	2,659	20,508		31							
Total—												
1904			43,795									
1907			252,373									
1908			18,018									
1910	14,411		196,871									
1911	20,284		156,349									
1912	13,972	405	386,192		1,604							
1913		70	288,988		129							
1914	12,259		93,927									
1915	1,540	2,175	332,628		196							
1916		2,772	798,852									
1917	11,401	8,822	198,510	5	2,725							
1918	11,761	168,723	895,210	29	12,396							
1919	21,096	75,377	177,747	190	5,421							
1920	16,039	32,297	360,445	787	12,672							
1921	5,391											
1922	6,630	19,793	643,803		5,477							
1923	8,667	15,916	464,098	51	11,080							
1924	27,546	134,925	2,926,685	30	8,888							
1925	18,225	205,902	1,031,621	112	6,454							
1926	17,634	116,402	2,873,736	323	18,167							
1927	93,265	212,432	1,458,098	216	8,331							
Hinchinbrook Entrance district:												
Anchor Bay—												
1917			11,442									
1926		2,099	13,358		1							
1927		373	4,740									
Etches, Port—												
1913			1,094									
1914	739											
1917		11,212	32,083	48	780							
1918	167	93,619	78,076	57	48							
1919		20,583	293		27							
1920	4	16	4,531		12							
1923		657	25,762									
1925		13,011	80,768		2							
1926	719	12,793	111,671		4							
1927	1,819	30,161	275,658	57	819							
Rocky Bay—												
1918		2	5,649		14							
1925		6,755	35,960		9							
1926	10	14,482	12,456									
Shelter Bay—												
1917			3,870		16							
1923			1,534		1							
1925		759	4,483		542							
1926	2	826	6,794		15							
1927	1,088	10,200	93,233	100	622							
Zaikof Bay—												
1917		4,472	462	3								
1918	31	1,437	12,528									
1919		181	705		6							
1920	2	26	1,922		5							
1925	824	5,511	56,567	159	271							
1926	1,032	10,607	149,282	162	1,351							
1927	413	5,376	81,099		237							
Unallocated—												
1917			5,597									
1919		560	2,635									
1927	290	4,120	51,623	32	256							
Total—												
1913			1,094									
1914	739											
1917		15,684	53,454	51	796							
1918	198	95,618	98,888	57	62							
1919		20,764	998		33							
1920	6	42	6,453		17							
1923		657	27,296		1							
1925	824	26,036	177,778	159	824							
1926	1,763	40,807	293,561	163	1,371							
1927	3,610	50,230	506,353	189	1,924							

TABLE 1.—*Salmon caught and fishing appliances used in the Prince William Sound district, 1904 to 1927*—Continued

Year	Cobos	Chums	Pinks	Kings	Reds	Beach seines		Purse seines		Gill nets		Traps
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated, eastern part:												*Number*
1904			530,172									
1913			4,542	500								
1915			42,328		1,303							
1916	47,746	42,529	2,088,469		22,000							
1917	16,383	103,258	1,203,284		12,553							
1918	43,150	401,297	1,000,633	112	9,512							
1919	13,839	158,749	320,006	1,335	9,295							
1920	15,205	71,709	1,444,911	955	14,962							
1921	1,000		2,200									
1922			84,916		340							
1923	9,162	26,444	688,172	3	3,033							
1924		4,749	62,561		81,667							
1925	4,333	47,402	442,986	1,297	11,278							
1926	20,768	20,103	410,413	83	1,696							
1927	80,919	30,992	211,632	3	2,277							
Total, eastern part:												
1904			573,967									
1907			252,373									
1908			18,018									
1910	14,411		196,871									
1911	20,284		156,349									
1912	13,972	405	386,192		1,604							
1913		70	415,277	500	129							
1914	12,998		217,636									
1915	6,915	2,175	438,355		1,499							
1916	47,746	45,301	2,969,312		22,000							
1917	41,498	254,655	1,968,207	280	35,958							3
1918	81,963	1,054,197	2,795,333	439	46,754							15
1919	56,840	403,143	616,095	1,768	35,827							25
1920	37,030	180,934	2,657,529	2,221	53,109							27
1921	8,797	2,124	2,200		14,692							
1922	7,932	33,841	975,866	252	22,624							2
1923	18,291	75,774	1,439,891	505	34,975							3
1924	33,458	308,570	4,250,318	210	105,162							9
1925	41,014	547,288	2,239,137	1,738	36,464							15
1926	52,128	412,784	5,880,809	717	38,218							19
1927	197,861	477,176	2,994,207	591	27,957							29
Grand total:												
1904			573,967	253	109,200	7				10		
1905					100,000	2				10		
1906					60,578	2				5		
1907			252,373		17,692	2	280			5	300	
1908			18,018		117,018	2	315			15	953	
1909					150,412	1	150			20	1,067	
1910	14,411		196,871		68,122	2	290			20	1,000	
1911	20,284		156,349		23,130	3	450			16	800	
1912	15,563	405	401,892		47,549	5	615			16	950	
1913	406	70	425,574	1,003	75,412	6	550	2	180	27	1,250	1
1914	13,001		224,906		72,348	2	300			11	825	
1915	6,915	2,175	449,174		52,111	5	410	13	4,190	19	2,166	
1916	47,746	45,918	3,270,282	6	72,321	9	945	21	5,100	19	1,250	
1917	44,557	370,309	2,590,563	364	222,154	48	4,630	49	6,440	69	5,800	3
1918	100,247	1,341,887	4,302,646	557	249,092	70	8,110	64	8,841	97	7,873	18
1919	72,836	558,522	1,008,312	6,930	152,682	39	5,351	61	7,689	111	10,280	42
1920	89,378	260,963	5,314,747	6,408	129,655	54	4,860	63	9,052	217	15,844	47
1921	9,316	3,499	12,644		92,571	17	1,300	3	450	32	3,200	1
1922	8,962	50,517	2,421,272	286	140,736	19	1,750	7	1,030	80	4,500	5
1923	26,889	111,582	2,447,006	530	170,050	19	3,200	27	2,780	94	8,428	7
1924	69,431	385,251	8,395,901	1,219	158,484	24	1,540	21	2,995	62	4,200	21
1925	84,408	780,956	4,085,084	3,325	96,703	24	1,800	35	5,490	50	4,500	30
1926	78,607	587,351	11,153,663	2,153	157,313	21	2,065	62	6,565	30	5,325	40
1927	258,816	655,159	6,124,911	3,094	118,118	6	695	95	7,830	8	640	64

NOTE.—No catches were reported in the years omitted from each division of this table.

There follows a discussion of the catches at the several localities in each subdivision of the sound, in which the data in respect to the distribution of salmon and the development of the fishery at each place will be considered. After this a section is devoted to the salmon fisheries of Prince William Sound as a whole.

WESTERN PART

KNIGHT ISLAND PASSAGE DISTRICT

This district embraces all localities of the mainland and adjacent islands within and bounded by a line from Cape Fairfield on the west through Montague Strait to Point Helen at the southern extremity of Knight Island, thence along the watershed of that island, across Ingot and Eleanor Islands to Point Eleanor and thence to the point on the south side of the entrance to Port Nellie Juan.

Bainbridge Passage.—These data include a small catch of pinks reported from Big Bay in 1926. Although a small catch of pink and red salmon was reported from this passage in 1913, no serious fishing effort was made here until 1917 when 24,191 pinks and 105 reds were taken. The catch in 1918 was 79,443 pinks, 5,040 chums, and 1,696 reds, but it declined rapidly thereafter (with no catch reported from 1921 to 1924) until in 1927 only 470 pinks, 322 chums, and 1,565 cohos were taken. No reds or kings were taken in 1926 or 1927. In the 8 years for which data are available, catches of cohos were made in 3 years, chums in 4, pinks in each year, kings in 2, and reds in 5. There are several possible explanations for such irregularity: (1) The runs may be of local origin and easily exhausted; (2) the routes of migration may not be constant, or (3) the fishing operations may have varied in different years. So far as these data indicate, the fishery in Bainbridge Passage appears to be irregular and uncertain.

Chenega Creek and Island.—Prior to 1918, the name "Chenega" seems to have been used interchangeably with Eshamy as there is no authentic record that any salmon were taken at what is now known as Chenega until after 1917. No doubt exists that there was confusion in the use of these names as no catch was reported from Eshamy in 1904 or from 1906 to 1911, inclusive, whereas in 1905 none was reported from Chenega. Moser (loc. cit.) states "Chenega is between Rubber Boot and Point Nowell and has the largest run of redfish in Prince William Sound. In 1895 it furnished about 100,000 but a safe value is 50,000." The only stream of consequence between the points named by Moser is Eshamy, whereas the stream now known as Chenega is on Chenega Island, several miles south of Point Nowell. As the first red-salmon fishery in the western part of the sound was developed at Eshamy and as the entire catch at Chenega from 1904 to 1911 consisted of red salmon, there is slight reason to question the assumption that these catches actually came from Eshamy and are properly allocated to that stream. In late years (beginning with 1918) the east shore of Chenega Island has become one of the most productive fishing areas in the western part of the sound, due largely to the operation of traps. Table 2 shows graphically the catch of cohos, chums, pinks, and reds at Chenega.

TABLE 2.—*Graphic table showing the catch of salmon at Chenega, 1918–1927*

[Each letter represents the following number of fish: Reds, 2,000; pinks, 20,000; chums, 1,000; and cohos, 250]

Year	Reds	Pinks	Chums	Cohos
1918	mmmmMmmmmM	mmmmMm	mmmmMmmmm	mmmmMmmmm
1919	mm	m	mm	mm
1920	mmm	mmmmMmmm	mmm	mmmmM
1921	mmmmM	m	m	mm
1922	mm	mmmmMmmmmMmm	mm	m
1923	m	mmmmM	m	m
1924	mmm	mmmmMmmmmMmmmm	mm	m
1925	mmmmM	mmmmMmm	mmmmM	m
1926	mmmmMmmmmMmmmmM	mmmmMmmmmMmmmmMmmmmMm	mmmmMmm	mmmmMm
1927	mmmmMmmm	mmmmMmmmmMmmmmMmmmmMm	mmmmMm	mmmmM

The coho fishery in this locality is relatively unimportant; and the catch each year was probably made incidental to fishing for other species, especially pinks, and has no value as indicating the extent of the coho runs. This situation is true also in respect to the chum fishery as this species, like the others, was taken in general fishing for all kinds of salmon, largely by traps. The catch of chums at Chenega dropped from 8,527 in 1918 to 1,341 in 1919, or at about the same ratio as the catches of other species declined, indicating that the fishing effort was less. The fluctuations in catch from 1918 to 1924 correspond with those of the pink salmon in the same years, and the increase after 1924 was equally rapid. The trend of the catch is unmistakably upward in approximately the same ratio as the rise in the trend of the pink-salmon catches. All of these facts indicate a close relationship between the catches of chums and pinks which is due, undoubtedly, to the fact that chums are taken chiefly incidental to the taking of pinks.

The pink-salmon catch at Chenega exceeded that in any other locality in the Knight Island Passage district, which makes Chenega one of the most important districts of the sound. It has increased steadily in each even year from 1918 to 1926. Disregarding the season of 1921, the odd years have also shown a progressive increase in production until the catch in 1927 was 412,498, about 7,000 less than the catch in 1926—the best the locality had known. These facts show conclusively an upward trend of the fishery and that the run in the off year of 1927 was abnormally large without apparent cause. A similar unexpected increase in the catch of pink salmon in 1927 was noted in other districts and was discussed in Part II of this series (pp. 709 and 710).

Chenega has produced a few thousand red salmon every season from 1918 to 1927. As stated above, this stream was in early years confused with Eshamy and until the installation of traps along the east coast of Chenega Island all salmon reported as coming from Chenega undoubtedly were taken at Eshamy. It may be assumed safely, moreover, that the red salmon taken in the traps along Chenega Island since 1918 were Eshamy fish and that their migration route was northward through Knight Island Passage.

King salmon have not been reported from Chenega since 1920. Beginning in 1918, catches were made in three years, a total of 211 fish being taken.

Drier Bay.—Scattered catches of coho, chum, and red salmon were made in this bay, but its importance as a fishing locality rests chiefly in the production of pinks. Only one small catch of that species was made before 1918; but since then the catches have increased, though somewhat irregularly, and culminated in a catch of 119,678 pinks in 1924. This comparatively large catch gave prominence to the locality as a producer of pinks, but so few seasons for which data are available in this review have since elapsed that the future of the district remains uncertain. In 1926 and 1927, the catches were 48,133 and 41,044, respectively, which may be regarded as very good yields for a small district having only a few small streams.

Eshamy Bay and Lagoon.[4]—From 1904, the year in which the Government began the systematic collection of fishery statistics of Alaska, the record of catches in this locality is unbroken through 24 years. Production has been consistently good, considering that the streams are few and small and that over-fishing was the rule rather than the exception for years. Exclusive of 1921, no serious drop in production of any species occurred until 1924. The reduced production in 1924 and subsequent

[4] Including also catches reported from Rubberboot Creek, located near the northern entrance to Eshamy Bay.

years was probably due to the effect of new regulations restricting operations rather than to a material decline in the abundance of salmon. These regulations prohibited all commercial fishing within 1,000 yards of the mouth of Eshamy Creek and required a distance interval of 200 yards between all set nets in the bay and lagoon. The regulations effective in 1925 and continued without modification in 1926 and 1927 completely closed the lagoon to commercial fishing for salmon and prohibited fishing operations within 1,000 yards of the mouth of Rubberboot Creek. It seems reasonable, then, to attribute the reduced catch at Eshamy from 1924 to 1927 to the enforcement of these regulations, and consequently the catches in these four years are not comparable with those of preceding years.

Eshamy Creek is the outlet of a small lake and gained prominence among the local fisheries in the early days of the packing industry by reason of the red salmon it produced. It was the stream most preferred by the fishermen from the canneries at Odiak and later by the cannery at Orca. A saltery was once operated within a few yards of its mouth near the head of the lagoon. Fishing was easy and often destructive; competition was keen between fishing crews; and the law was frequently disregarded, as court records at Valdez and Cordova show. Red salmon alone were wanted. No effort was made to take pinks until 1912, at least none was reported from Eshamy before that year. The runs of cohos, chums, and kings, as indicated by the catch, are unimportant. A few hundred cohos were taken in each year since 1912 except two, 1916 and 1926. Chums were caught in slightly larger numbers without interruption from 1916 to 1927. A few kings were taken in most years, but the largest catch in any one season was only 64. No analysis of the data for these species of minor importance seems advisable at this time.

A graphic picture of the catch of red salmon at Eshamy from 1904 to 1927 is shown in Figure 4, and the trend of the catch, calculated on a 5-year moving average, is also shown for the period up to 1923 inclusive. The trend was not figured beyond that year on account of the influence of the new laws and regulations, mentioned above, on the catch in 1924 and subsequent years. In general, it is seen that good catches were secured up to 1910. Then followed a period of six years in which the catches were light and the trend correspondingly lower. Beginning in 1917 there was another period marked by large catches—nearly, but not quite, the equal of those immediately preceding 1910. This lasted until 1924, when the new regulations became effective and since which time the catch has been held at a very low level. For a small stream which has been intensively fished and which has supported a relatively small run, probably never over a few hundred thousand red salmon, the Eshamy run has held up well and apparently shows no serious depletion.

The percentage deviation of the catch from the trend is given in Figure 5. (See Pt. I, pp. 61–63 for an explanation of the use here made of the deviation from the trend and the correlations in the deviations at intervals.) The fluctuations in these deviations are distinct and regular, indicating definite cycles in the catches (and presumably therefore in abundance) at regular intervals. These cycles appear consistently through both good and poor years and are as well marked during the relatively unproductive years from 1910 to 1916 as during the productive periods that preceded and followed. Coefficients of correlation at 4 and 5 year intervals are as follows: Four-year interval $r = 0.69 \pm 0.102$; 5-year interval $r = 0.76 \pm 0.085$. Both of these correlations are high and sufficiently greater than their respective probable errors so that their significance is undoubted. Coefficients were not calculated for

other intervals but it is evident by inspection that the correlations at both 3 and 6 year intervals would be insignificant.

This high correlation at two different time intervals (four and five years) is naturally to be interpreted as indicating that the runs are made up of 4 and 5 year fish in approximately equal numbers, and it has seemed important to attempt to devise some measure of correlation that would take this into consideration. After trying various methods the simple scheme was adopted of correlating each catch with the average catch of the fourth and fifth preceding years. Thus the catch of 1910 was paired with the average for 1905 and 1906, the catch of 1911 with the average for

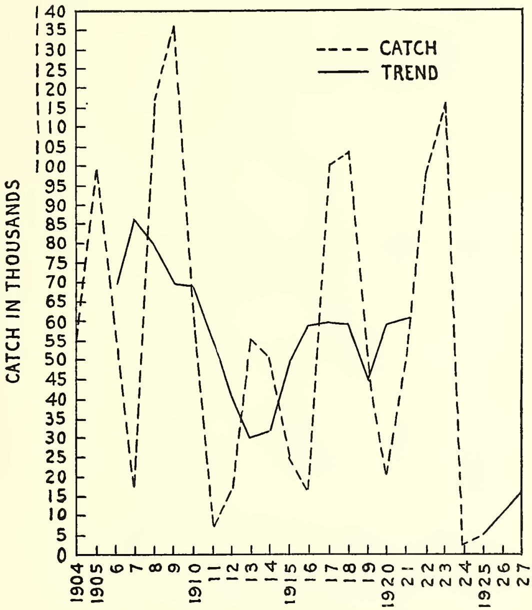

FIGURE 4.—Catch of red salmon at Eshamy

1906 and 1907, etc. Such a procedure, of course, gives equal weight to the two parent years—which seemed advisable in this case on account of the nearly equal value of the correlation coefficients at 4 and 5 year intervals. Any other weighting, of course, could have been used if there had been any good reason, biological or other, for so doing. The results were interesting since r calculated in this manner proved to be 0.89 ± 0.040, a distinctly higher and more significant correlation than at either 4 or 5 year intervals. This apparently confirms the interpretation that the Eshamy fish are predominantly 4 and 5 years old at maturity and that the two age groups are present in about equal numbers, or, more properly, are produced from each brood in approximately equal numbers.

Falls Bay.—Statistics are available showing the catch of salmon at Falls Bay for five years, from 1922 to 1927, with the exception of 1923. All species have been taken, but the catches have always been small. Red salmon and pinks are taken in approximately equal numbers, although during the last three years, 1925 to 1927, the reds were more abundant than any other species. Records indicate that the fishery was conducted entirely by means of gill nets, but no information was presented to show that operations were confined strictly to the bay. In view of the fact that no salmon were taken here until recent years, it is probable that the bay has no local

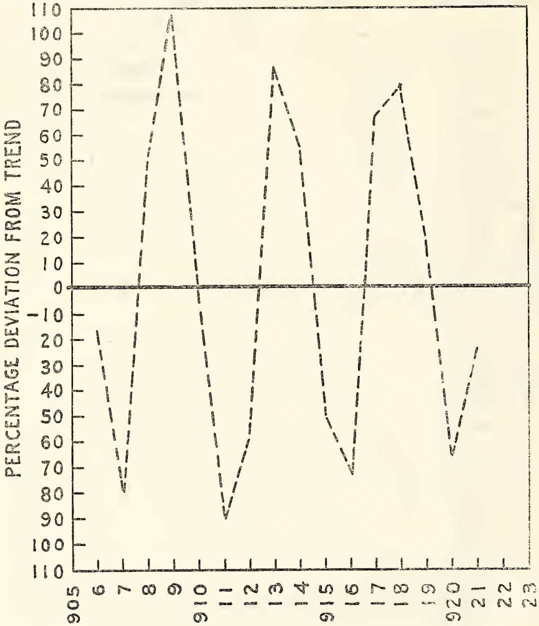

FIGURE 5.—Percentage deviation from the trend of the catch of red salmon at Eshamy

run of red salmon and that gill nets set at the entrance of the bay intercept fish moving toward red-salmon streams in more northerly localities. This assumption would not necessarily apply to pinks and chums, as they are found in all parts of the sound, including Falls Bay.

Granite Bay.—The fishery at this locality is also of comparatively recent origin, practically nothing having been taken there before 1924. It produced pink, red, chum, and coho salmon. The catch of reds increased steadily in the four years from 1924 to 1927 and now gives the locality singular importance by reason of its proximity to Eshamy Bay and its rather sudden development. Inasmuch as the salmon reported from Granite Bay were taken in gill-net fishing, there is a possibility that

they came from a local run and were caught well within the bay. This possibility is suggested by the fact that a lake-fed stream enters at the head of the bay which might support a small run of red salmon. However, if the catches were made off the entrance of the bay, the presumption is that the Eshamy run provides the fish reported from Granite Bay. On account of the fact that the fishery here has developed almost entirely since the stringent regulations affected the fishery at Eshamy, the latter hypothesis seems the more probable.

The catch of pinks has fluctuated considerably in the four years, disclosing two surprising and contradictory phenomena. The records for 1925, an odd year in which the run elsewhere in Prince William Sound was small, show that the catch was 82,581, the largest ever made at Granite Bay. In 1926, the year of the largest run of pink salmon ever known in Prince William Sound, this locality produced only 6,213 pinks, a direct reversal of anticipated results. While nearly all other localities were showing much larger production in 1926, Granite Bay fell off more than 92 per cent in yield of pinks, 87 per cent in chums, and 57 per cent in cohos, but gained 102 per cent in production of reds. This indicates a peculiar condition of the fishery which data at hand do not explain.

Jackpot Bay.—In the early days of salmon fishing in Prince William Sound, Jackpot Bay was rated by Moser (1899, p. 138) as good for 7,000 red salmon annually. It was probably fished as early as Eshamy Lagoon, but the first recorded catch was made in 1911, consisting of 5,885 red salmon. In 1914, the catch had declined to 1,977. The bay was then abandoned and not fished again until 1917 in which year 21,770 reds were caught. Another decline started in 1918 and terminated in 1920 with a catch of 80 reds, 6,967 pinks and 67 chums. Since then Jackpot Bay has not been fished. In 1925, it was permanently closed by departmental regulation for a distance of 2,000 yards from the mouth of the stream at the head of the bay. The closed area was extended to 3,000 yards in 1927.

Latouche Passage.—The available records show that this locality was fished only in 1919, 1925, and 1927. Catches were uniformly small for all species except in 1927 when 105,643 pinks were reported. This extraordinarily large catch is one of the exceptional occurrences for which no explanation can yet be given. If these figures are reliable they would indicate that the fishery in Latouche Passage may be developed into one of considerable importance, but the data are still too fragmentary to warrant any conclusions.

Main Bay.—This locality has been fished for years by a single company, but operations were not continuous, indicating that the runs of salmon are of little importance. All species except kings were taken but the catch consisted mainly of pinks and reds. The catches of pinks apparently have been decreasing while those of reds have increased—a condition similar to that at Falls and Granite Bays. As gill netting was the preferred method of fishing, it seems likely that the red salmon taken in Main Bay were migrating to other waters, there being no evidence to indicate the existence of a local run.

Point Nowell.—Catches of salmon were reported from this locality in three years. The first was made in 1917 and consisted chiefly of red salmon, the second in 1925 when only a few thousand salmon of four species were taken, and the third in 1927 when the number of pinks increased to 14,943 and that of reds, chums, and cohos dropped to a few hundred. This locality is not an important producer of salmon; the catches are small and are made by traps or set nets, yet it might seem that appliances set along the Point Nowell shore should intercept fish

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going to Eshamy Bay or the more northern localities just as they apparently do at Falls Bay, for example.

Prince of Wales Passage.—Beginning in 1919, fishing in these waters has been carried on each year through 1926, except 1925. In that time the catch of red salmon, though never large, has shown considerable fluctuation; but the number taken in 1926 was next to the largest ever reported from the passage. The catch of pinks has increased materially although none was reported during the three years 1921 to 1923 nor in 1925 or 1927. The large catches of 1924 and 1926 were made by traps, and it appears probable that they were not driven in the odd years when only small runs were expected. The streams of the passage are undoubtedly small and not capable of supporting large local runs so that the capture of more than 100,000 salmon in Prince of Wales Passage in 1926 indicates that the salmon taken there were chiefly migratory.

Squire Island, Thumb Bay, and Whale Bay.—Of these three localities, Whale Bay only was fished before 1926. It produced in 1918 and 1920, small numbers of chums and pinks. The bay was not fished again until 1926 when 36,553 pinks were taken and a limited number of reds and chums was also captured. The Squire Island and Thumb Bay data cover only two years but catches were fair at both places. The Squire Island catches were taken (undoubtedly from salmon on their migration to streams beyond) by a trap located at the south end of the island. The data are too few to warrant any attempt at analysis. The unallocated catches in the district include salmon from Chenega Passage in 1919 and 1920; from Crafton Island and Dangerous Passage in 1918 and 1919; from Eshamy Passage in 1920; from Flemming Island in 1927; from Hawkins Bay in 1917; from Knight Island in 1913, 1917, and 1918; from Little Bay in 1920 and 1926; from Paddy Bay in 1913 and 1917; and from Mummy Bay and Sleepy Bay in 1926.

The Knight Island Passage district, as a whole, shows a rather steady production of red salmon from 1904 to 1927. The red-salmon catches are obviously dominated by the Eshamy runs since the figures for the entire district closely parallel those for Eshamy alone and are only slightly higher up to 1924. Since 1924 the catches in the entire district have been markedly higher than those from Eshamy due, without doubt, to the limitation of fishing in Eshamy Bay and the subsequent increase of fishing effort outside, but in localities where the fish bound for Eshamy are running. While the regulations have reduced the catch of red salmon in the immediate vicinity of Eshamy, it is apparent that they have not materially affected the total catch in the district. This evidently means that the gear formerly fished close to the mouth of the stream has been just as effective when moved farther away or else that it has been replaced by other gear which has been effectively operated at a distance from the stream mouth. It is important to note that, at least in this instance, regulations designed to reduce the dangerous concentration of fishing effort at the mouth of the stream still permit a reasonable catch. In the case of pink salmon, the district shows larger catches in 1926 and 1927 than ever before and a consistently better run in each off year since 1921. Chums are not taken in large numbers in this part of the sound, the largest catch being 21,033 in 1918. Small runs may be characteristic of this district, yet on the other hand the small catches may be accounted for in that little or no effort was made to take chums. Cohos are also captured in comparatively small numbers, but the supply was as large in 1927 as in any preceding season. The evidence indicates that here, as elsewhere, cohos and chums are taken chiefly incidental to the fishing for other species. King-salmon runs are insignificant, catches

are small and scattered, ranging from 254 in 1920 to 14 in 1927, the greater part coming from traps along the Chenega shore. Table 3 gives a graphic picture of the catch of all species except kings.

TABLE 3.—*Graphic table showing the catch of salmon in the Knight Island Passage district, 1904–1927*

[Each letter represents the following number of fish: Reds, 10,000; pinks, 50,000; chums, 2,000; and cohos, 1,000]

Year	Reds	Pinks	Chums	Cohos
1904	mmmmMm			
1905	mmmmMmmmmM			
1906	mmmmMm			
1907	mm			
1908	mmmmMmmmmMmm			
1909	mmmmMmmmmMmmmm			
1910	mmmmMmm			
1911	mm			
1912	mm	m		m
1913	mmmmMm	m		m
1914	mmmmMm	m		m
1915	mmm	m		
1916	mm	m	m	
1917	mmmmMmmmmMmmm	mmm	mmmmMmmmmM	m
1918	mmmmMmmmmMmmmm	mmmmMm	mmmmMmmmmMm	mmmmMm
1919	mmmmMmmmm	mmm	mmmmMmmm	mmmm
1920	mmmm	mmmmMmm	mmmm	mmmm
1921	mmmmMm	m	m	m
1922	mmmmMmmmmMm	mmmmMmmmmMmm	mmmmM	mm
1923	mmmmMmmmmMmmm	mmmm	m	mmm
1924	mm	mmmmMmmmmMm	mmmmM	mm
1925	mmm	mmmmMm	mmmmMmmmm	mm
1926	mmmmMm	mmmmMmmmmMmmmmMm	mmmmMmmm	mmm
1927	mmmmMmmm	mmmmMmmmmMmmmmM	mmmmMmm	mmmmMm

MONTAGUE STRAIT DISTRICT

The Montague Strait district includes all waters east of a median line through Montague Strait to Point Helen at the southern end of Knight Island, thence along the watershed of that island, across Ingot and Eleanor Islands, thence north of Smith Island and south to Montague Point, thence along the watershed of Montague Island to Cape Cleare, and thence to the point of beginning in Montague Strait. This district comprises an area in which no fishing was carried on before 1917, except at Bay of Isles on the east coast of Knight Island where a small run of red salmon was exploited as early as 1912 and fished intermittently until virtually exhausted.

Aside from a few small catches, classed as unallocated, all salmon taken in this district came from the west cost of Montague Island. The development of a fishery in this region commenced in 1917 but did not reach large proportions until 1924. The fishery is, therefore, quite new and the data are necessarily limited to so few years that analysis must be confined largely to a discussion of the catches of pink salmon. This district embraces seven localities, each of which will be considered separately as far as data warrant. The unallocated catch in this district includes salmon reported as taken at Marsha Bay in 1917; at Montague Point in 1925; at Montague Island in 1917, 1919, 1926, and 1927; and at Rocky Point, Sandy Point, and Green Island in 1927.

Bay of Isles.—A stream, the outlet of a small lake, enters the head of the bay where a fishery was conducted intermittently from 1912 to 1926. In the eight years of operation, the catches consisted chiefly of red and pink salmon, but they were small and irregular and gave the stream little importance as a producer of salmon. In 1925, the middle arm of the bay was closed to all commercial fishing for salmon but in 1926 this restriction was removed and the west arm was closed—a restriction

that is still in force. No catches were reported in the years 1923 to 1925, inclusive; but the bay was fished again in 1926, although only small catches of chums, pinks, and reds resulted from the operations. Nothing in the available data indicates that a valuable salmon fishery can be established here; in fact, the conservation of the local run even if fully rebuilt, will be of little material benefit to the fisheries of the sound. Continued closure of this locality appcars to be a conservation measure of very limited value.

Cape Cleare.—Although this locality (the southwestern extremity of Montague Island) was certainly fished in earlier years, the only definite records are of moderate catches made in 1926 and 1927. In the earlier fishing, gill nets or seines were probably used, but the recent catches were made by a trap. All species of salmon were taken, which, named in the order of their numerical value were pinks, cohos, kings, reds, and chums. A catch of 9,463 cohos and 935 kings seems to throw some light on the question of the origin of the runs which are intercepted at this point. They may be strictly Prince William Sound fish but there is a possibility that the run, particularly of kings, is bound for some other region, since no tributary of the sound is known as an important king-salmon stream.

Glacier Bay.—Data for 1926 and 1927 only are available for this locality which is a shallow indentation on the west coast of Montague Island about midway between Cape Cleare and Montague Point. This too is a trap fishery of recent development. The larger catch, including all species, occurred in 1926, due to the phenomenal run of that year. Inasmuch as the streams of Glacier Bay are comparatively unimportant, these catches may be regarded as coming from the general runs of Prince William Sound that have been shown to enter through Montague Strait.[5]

Hanning Bay.—Like other places on the west coast of Montague Island, Hanning Bay is a new field the exploitation of which had not been attempted before 1920 when experimental fishing was begun by a company operating a cannery at Seward. A trap was driven in the bay and made an encouraging catch of all species of salmon in the first year it was operated. It is possible that this locality was prospected in 1919 but no catch was recorded under the name of Hanning Bay until 1920. Apparently it was then neglected for several years as the next recorded catch in this locality was made in 1924. Thereafter the bay was fished regularly and produced substantial catches of pinks, a few hundred kings, and several thousand cohos, chums, and reds, thus giving it prominence as one of the best fishing localities in the Montague Strait district. As Thompson has shown (loc. cit) the traps at Hanning Bay in all probability merely intercept a part of the main run of salmon entering the sound through Montague Strait. The streams of Montague Island can not be large on account of the nature of the island and they consequently provide very limited areas for spawning. It is doubtful also that all species of salmon spawn in these streams.

Macleod Harbor.—According to available records, Macleod Harbor was not fished regularly before 1920 although 1,500 pink salmon were taken there in 1918. In 1920, the commercial catch was larger than that of any other locality in the Montague district and ranks fourth in size among the localities of the sound. Records for the next three years show no catches in this bay, yet it is probable that some salmon were taken here but not allocated to the waters where caught, as often happened. Fishing was resumed in 1924 and continued through the next three years

[5] Salmon Tagging Experiments in Alaska, 1929, by Seton H. Thompson. Bulletin, U. S. Bureau of Fisheries, Vol. XLVI 1930 (1931). Document No. 1084.

with surprising results. Out of a total production of 868,594 salmon in the Montague district in 1924, Macleod Harbor produced 862,773—a catch which has not since been equalled. There was a material falling off in catch of pinks and chums in 1925, cohos decreased slightly, while kings and reds increased. In 1926, large gains were made in the catches of chums, pinks, and reds, but kings declined 8 per cent and cohos about 50 per cent. The catch of chums, pinks, and reds fell off in 1927, whereas that of cohos and kings increased. In the five years for which data are available, the average yield of cohos was approximately 30,000; chums, 15,000; pinks, 416,000; kings, 1,562; and reds, 11,000.

The outstanding feature of the Macleod Harbor fishery is the consistently good catch of king salmon, which is larger than that in any other locality of the sound in the same years. The district is too new and data are too few for comprehensive analysis, but it is safe to say that the bulk of the catch came from passing runs rather than from runs to streams of Macleod Harbor. Catches were made exclusively by traps set near the entrance of the harbor, which in itself is an indication that the local runs, if any, are unimportant so that seining is not profitable.

Port Chalmers.—Chum and pink salmon were reported from this locality in six years, 1917 and 1918 and from 1924 to 1927. Catches of cohos and reds were insignificant, but those of chums and pinks have been of more importance. Contrary to the common rule, the largest catches of pinks were made in the odd years of 1925 and 1927, while all other localities in the Montague Strait district show larger catches in the even years. This place seems to have been fished chiefly by companies located at Cordova using seines. The total absence of kings and the small number of reds in the catches afford some reason for assuming that the salmon came from local runs to the streams of Port Chalmers. Evidence of the interception of migrating salmon at this point, as noticed at the more southerly localities of the Montague shore, is wholly lacking here.

Stockdale Harbor.—Small catches of pink salmon were made at this bay in three years, but the data are entirely too few for analysis. Although the catch in 1926 was larger than that of the other two years, none was made in 1927, and it would seem that the run is commercially unimportant. The unallocated catch in this district includes salmon reported as taken at Marsha Bay in 1917, at Montague Point in 1925, at Montague Island in 1917, 1919, 1926, and 1927, and at Rocky Point, Sandy Point, and Green Island in 1927.

The Montague Strait district, considered in its entirety, constitutes an area of relatively recent exploitation since, prior to 1920, it was not known to offer any possibility for profitable fishery development. Small catches had been made in the bays of the east coast of Knight Island and along the northwest coast of Montague Island, but not until traps were driven in 1920 at points on the southwest coast of Montague was it discovered that a large part of the Prince William Sound run entered through Montague Strait and could be reached by traps driven from the shore. In the last four years, 1924 to 1927, catches have reached rather large proportions and occasioned interest in the possible effect they may have upon the runs of salmon to the inland waters of the sound. In reviewing the data for this district, it was pointed out that there was little or no evidence to support the notion that salmon moving along the west coast of Montague were bound to local streams. That dea seems untenable in view of the physical peculiarities of the island which is long and narrow and traversed lengthwise by a high and rugged range of mountains. The most plausible theory, and one supported by the evidence of tagging experiments, is that the salmon passing

along this shore are not bound to any particular section of the sound but disperse in all directions.

PORT WELLS DISTRICT

In this district are embraced all waters of Prince William Sound north and west of a line from the south entrance of Port Nellie Juan to Point Eleanor on Eleanor Island and thence to the southernmost point of the peninsula between Esther Passage and Eaglek Bay. Thirteen localities in this district are given individual consideration in this analysis. The following combinations of data have been made: A catch made at Beattic in 1917 was included in the catch at Bettles Bay; a catch at Surprise Cove in 1920 was added to the Cochrane Bay catch; Coghill River figures include catches reported from Coghill Bay in 1919, 1926, and 1927; from Coghill Lake in 1919, and from College Fiord in 1919, 1920, and 1924; Culross Passage catches are combined with those from Culross Island in 1925 and 1927, from Colms Passage in 1919, and from Goose Bay in 1919 and 1922; Pigot Bay catches include salmon reported from Pichet Bay in all years; Port Wells catches include fish from Hobo Bay in 1918, from Passage Canal, sometimes called Portage Bay, in 1918 and 1919, from Blackstone Bay in 1918, 1919, and 1920, from Blackstone Glacier, Entry Cove, and Harrisons Lagoon, also called Hearigans Lagoon, in 1920, from Wells Passage in 1920 and 1924, from Culross Bay in 1925, and from Perry Passage in 1927.

Bettles Bay.—This bay is a small tributary of Port Wells, indenting the mainland about midway between Point Pigot and Point Pakenham. Salmon of all species have been taken here but only pinks in quantities. Catches were made in seven years covering the period from 1918 to 1927, with the exception of the three years from 1921 to 1923. The most productive season, 1918, shows a catch of 119,656, chiefly pinks, but in 1919 the catch dropped to 391 salmon, consisting of chums, pinks, and reds. Since then, wide fluctuations have occurred and the catch has dwindled from the large total of 1918 to 14,460 chums and pinks in 1927. These fluctuations are doubtless due, at least in part, to faulty records, but the development of an important fishery in this locality is quite unlikely. The source of the fish taken here is probably local.

Cochrane Bay.—This locality, like Bettles Bay, has been fished seven years. Small catches of chums, pinks, and reds were made in 1918 and 1919, but in 1920 the catch of pinks increased to 216,000. In the next three years, no catches were reported from this bay; however, in 1924, the catch was 450,000, chiefly pinks. In 1925 the catch declined to 50,000, while in 1926 and 1927 it was again relatively high, giving some assurance that a profitable fishery may be maintained in this locality.

Coghill River.—This river is the outlet of Coghill Lake; it enters College Fiord, the northernmost arm of Port Wells, at Coghill Point. Fishing has been somewhat irregular and was first carried on in 1914 for the red salmon obtainable there. Further exploitation began in 1917 by the operation of a trap directly at the mouth of the river, and a fair catch of reds and pinks was made in 1918 and 1919. Notwithstanding the fact that no fishing was done there during 1921 to 1923, the catch in 1924 was again poor. No catches were reported from this locality in 1925, and since then only chums and pinks have been caught. In 1925 waters within 2,000 yards of the mouth of the river were closed to all commercial fishing for salmon, a regulation which has been continued to the present time and undoubtedly accounts for the failure to take red salmon at this locality since 1924. The catches of chums and pinks were made in College Fiord at some distance from Coghill River.

Culross Passage.—Culross Passage has been one of the largest producers of pink and chum salmon in the Port Wells district. It is a narrow strait separating Culross Island from the mainland and is probably one of the routes used by salmon entering Port Wells, although the larger part of the catches were made by purse seines, indicating that the fish were schooled in considerable bodies. Long Bay, the only arm on the west side of the passage, was closed by regulation in 1925 and has not since been opened. The passage has been fished every year from 1917 to 1927, inclusive, except 1921 and 1923. In the last four years of this period, the catch of pinks was exceptionally high, while a fair number of chums was also caught. The other species were represented in the catches of nearly every year, but not in sufficient quantities to give such runs real significance. The largest catch of pinks was reported in 1926, which would naturally be expected in a season of such unprecedented runs as then occurred; but 1927 was also a good year, the yield being second only to the catch of 1926.

Point Culross.—Data for this locality cover two years, 1926 and 1927. The catches were made by a trap which intercepted the runs to Port Wells along an abrupt shore where the water is deep and where only floating traps can be used. Although data for only two years can have no immediate significance they are kept separate in view of the probability of future development in this locality. The same procedure has been followed elsewhere in this series.

Esther Passage.—This passage separates Esther Island from the mainland. It has been fished irregularly since 1914 and catches, apparently from local runs, have always been small. On the west side of the passage is a stream, the outlet of a small lake, which supports a small run of red salmon. The comparatively early exploitation of the fisheries of Esther Passage was probably due to the presence of these few red salmon. Nothing in the records at this locality gives promise of a valuable fishery in the future. If any considerable part of the salmon going to Port Wells enter through this passage, it might reasonably be assumed that a fishery of importance could be maintained, but there is no evidence that the passage is so used.

Hummer Bay.—This bay has provided catches of pink and chum salmon. The first catches were reported in 1918, the second in 1920, but not again until 1924. From then until 1927 fishing was carried on each season. As the catches in 1918 and 1920 bear little or no relation to those in 1924 and later, consideration is here given only to the data of the other years. Hummer Bay is a small indentation on the west side of Port Wells. In 1924 the entire catch was made by seines and in all probability was taken well within the bay. Since then more than half the catch came from a trap at or near the entrance of the bay, while in 1926 the trap made two-thirds of the catch. The even years show the largest production, though the catches in the odd years were relatively good. It can not be definitely determined, however, that all the trap-caught fish were Hummer Bay salmon, as it is probable that salmon going to more northerly waters of Port Wells were captured by this trap.

Long Bay.—This bay was referred to in the discussion of Culross Passage data. It was set out as a separate locality in order to localize as far as possible the larger catches in places where there was reasonable assurance that operations would be continued after 1927—the last year considered in this review. Fair catches of pinks and chums were made here in 1926 and 1927, notwithstanding that the bay had been closed to commercial fishing for salmon since 1924. Evidently the catches in subsequent years were made at the entrance of the bay rather than in the closed area and were reported as Long Bay fish in order to differentiate them from salmon

taken in other parts of Culross Passage. As the catches were made with seines, the salmon doubtless schooled at the mouth of the bay.

McClure Bay.—In the four years from 1917 to 1920 a few pinks and chums, with occasional cohos, kings, and reds, were reported from this bay. Production then ceased until 1925, when chums and pinks were again taken. Inasmuch as no salmon were reported from this bay in 1926, the best year in the history of the sound fisheries, or in 1927, also a good year, it would now seem that the locality has been abandoned or that fish taken here are reported with other catches.

Mink Harbor.—Mink Harbor is not indicated by name on Coast and Geodetic Survey Chart No. 8550, but is a local name applied to a small bay located on the west side of Port Nellie Juan, almost directly opposite the mouth of McClure Bay. According to the available data, fishing began here in 1918 with the catch of a few thousand chums and pinks. Nothing more was done until 1924, but, beginning then and continuing through 1927, catches were large and show progressive increases for the cycles of both even and odd years. In the four years for which there are continuous records the fishery has attained a position of real importance among the localities of the Port Wells district. It is a seine fishery and for that reason the correctness of the data may be questioned, as fishermen are disinclined to reveal the source of good catches. However, in the absence of proof to the contrary, the figures must be accepted as essentially correct. The record contains no evidence of depletion.

Port Nellie Juan.—Among the localities of the western part of the sound Port Nellie Juan comes next in size to Port Wells, and, like most other localities in that district, it is mainly a producer of pink and chum salmon. Catches were reported in two 4-year periods, from 1917 to 1920, inclusive, and from 1924 to 1927. The break in fishing in the three years from 1921 to 1923, likewise noted in the records for several other localities in this district, may mean that salmon taken in those years were reported only as coming from the sound rather than that there was no fishing at all. If catches were made, definite allocation was omitted and therefore analysis of data is correspondingly more difficult. Assuming the statistics to be correct, the catch of pinks in the even years increased from 165,840 in 1918 to 534,546 in 1924. In 1926 it dropped to 213,737, showing, in a year of great abundance elsewhere in the sound, a decided decrease in the catch as compared with that of the second preceding year without a noticeable change in the intensity of fishing. The catch in the odd years was much smaller, and the decline from 1925 to 1927 was even more marked than that from 1924 to 1926. No reason can be given for these changes, which may be due to faulty data or to shifts in the fishery of which there is no record. The catch of chums also fluctuated widely, finally dropping from 29,476 in 1925 to 1,460 and 1,350 in 1926 and 1927, respectively. This decline, if genuine, was probably due to reduced fishing effort for chums in favor of greater activity for pinks in this and other localities. A few hundred cohos and reds were taken irregularly, but these species are of negligible importance.

Pigot Bay.—This bay is a small arm on the west side of Port Wells just north of Point Pigot. Records show, except in 1919 when the catch was only 1,143, that it has produced annually from 22,000 to 54,000 pink salmon, exclusive of three seasons in which fishing was apparently suspended. Runs of chums were much smaller, and catches of cohos, kings, and reds were negligible. The pink-salmon fishery appears to be in no immediate danger of depletion, while the others have little economic importance.

Port Wells.—Port Wells proper with its tributaries, forms the largest arm of Prince William Sound; it has produced more salmon than any other locality in what is here called the Port Wells district, but fluctuations in the catch have been erratic. In 1912 and 1913, red salmon only were reported from this locality and they probably came from Coghill River. The next catch, consisting entirely of pinks, was made in 1917; thereafter fishing was prosecuted each year through 1927 although in 1921 only reds were taken while in 1923 the catch consisted wholly of pinks. In several years chums and reds were caught in appreciable numbers, occasionally cohos and kings, but pinks constituted the valuable fishery. Since 1922, the trend of the catch allocated strictly to Port Wells has been downward.

Looking at the Port Wells district as a whole, it is observed that the trend of the pink-salmon catch is decidedly upward and was not seriously affected by the total abandonment of fishing in the district in 1921 and the limited activities of the next two years. Although the catch in 1926 was smaller than in 1924 by 15 per cent, the catch in 1927 was 54 per cent larger than that in 1925, showing a tendency, frequently noted elsewhere, toward an equalization of runs as between the odd and even years. The situation in respect to red salmon is not encouraging. The run was never large and the catches declined rapidly after the peak of 1918 to a low level that was maintained up to 1927 except for slightly larger catches in 1924 and 1925. Some allowance should be made, however, for the effect of legal restrictions on fishing at Coghill River as that was the chief red-salmon locality in the district although a stream on the eastern slope of Esther Island once produced a few thousand.

Coho and king salmon data are too fragmentary to warrant detailed consideration. Chums were fairly abundant in some years, notably 1918 and 1925, but in 1921 and 1923 none was taken, while in 1922 the catch was negligible. The commercially important fishery of this district is centered, of course, in the pink-salmon runs, and the catches as already indicated appear to be increasing in nearly all localities. Graphic Table No. 4 presents a picture of the pink and red salmon fisheries in this district.

TABLE 4.—*Graphic table showing the catch of reds and pinks in the Port Wells district, 1917–1927*

[Each letter represents the following number of fish: Reds, 2,000, and pinks, 100,000]

Year	Reds	Pinks
1917	mmmmMmmmmMmm	m
1918	mmmmMmmmmMmmmmMmmmm	mmmmMmmm
1919	mmmmMmm	mm
1920	mmmm	mmmmMmmmmMmm
1921	mmmm	
1922	m	mmmmM
1923		m
1924	mmmmMmmmmMmm	mmmmMmmmmMmmmmMmmmmM
1925	mmmmMmm	mmmmMmm
1926	mm	mmmmMmmmmMmmmmMmm
1927	mm	mmmmMmmmmM

EAGLEK BAY DISTRICT

This small district, embracing a single locality between Port Wells and Unakwik Inlet, was set apart from all others because salmon taken in Eaglek Bay are presumably derived strictly from local runs, entirely separated from those to neighboring waters. The figures include a catch reported in 1917 from "Eayek" Bay, an undetermined locality, if not intended for Eaglek Bay. It is possible, of course, that some of the fish taken in the bay are casual visitors actually bound for other waters, but it

seems very probable that most of the fish taken here are of local origin. Pinks and chums are taken in commercial quantities and the record is unbroken from 1917 to 1927, except for 1921. The catch of pinks in the early and late years was relatively good, but from 1922 to 1925, inclusive, four poor catches were recorded, exclusive of 1921, a year in which no fishing was carried on. The catch in 1926 was one of the best on record and that of 1927 was good for an odd year, but it remains to be seen whether this is an indication of recovery from the unproductive period just preceding. This fishery has probably been conducted solely by means of purse seines as there is no evidence that traps were ever used. The catch of chums has been very irregular and has apparently declined, although the exceptional catch of 1925 may indicate that the fluctuations are economic rather than biological. The catches of cohos, kings, and reds were inconsequential and merit no discussion.

UNAKWIK INLET DISTRICT

This district extends from Kiniklik on the west to Granite Point on the east and the Naked Islands on the south. It includes five distinct localities, among them being Miners River, one of the best-known red-salmon streams of the sound. Aside from that fishery, exploitation of the district has developed in comparatively recent years.

Cedar Bay.—Cedar Bay is an arm of Wells Bay and is noted chiefly as a producer of pink salmon. Other species have been reported from the bay but not in sufficient numbers to constitute a fishery. Data are available for eight years from 1917 to 1927, omitting 1921, 1923, and 1925, and show wide fluctuations in catch from a high level of 145,530 in 1918 to a low level of 2,859 in 1927. The catches in 1920 and 1922 were far below that of 1918 but in more recent years have increased though they have never reached the level of 1918. Statistics for the odd years, covering only 1917, 1919, and 1927 give evidence of over-fishing and indicate a possibility of serious depletion. It appears probable that the run of the odd years is practically extinct, as a catch of only 2,859 fish after three cycles of unmolested escapement can not be regarded as an indication of an increasing supply.

Granite Point.—A trap was operated at this point in 1926 and 1927 and made good catches of pinks in both years. A few thousand chums and reds and a few hundred cohos were also taken. No information is available to show in which direction the salmon were moving when captured, so no conclusion can be reached as to whether they came from runs to Unakwik Inlet and Wells Bay or to more eastern localities. Analysis of such limited data is impracticable.

Miners River.—This river was regarded by Moser as capable of producing at least 10,000 red salmon annually. It was one of the first streams to be fished, yet the record of these early catches is lost in combination with those from other localities as none was credited directly to the river until 1904. It also appears that the locality was not fished in 1905, 1907, 1908, and 1920, and that it was abandoned after 1923. Except for three small catches of pinks at intervals of four and six years, a few kings in 1904, and 1 chum in 1923, Miners River has produced red salmon only. The catch has always been small, exceeding 9,000 just three times, and falling off gradually to 1,165 in 1923. Since 1911, the trend has declined regularly to 1921 when it reached the lowest point in 20 years. In 1925, Unakwik Inlet north of Jonah Bay was closed by departmental regulation to commercial salmon fishing thus ending all operations at Miners River. To what extent the catches of red salmon in Unakwik Inlet after 1917 were Miners River fish is not known, but in all probability some of them were bound to that stream, though captured in the lower part of the inlet. Figure 6 shows

graphically the catch and the trend of the catch of red salmon at this river from 1904 to 1923.

Unakwik Inlet.—The catches in this locality include some reported from Cowpen in 1922 and 1927, from Siwash Bay in 1917 and 1923, and from Unakwik Point in 1927. Salmon were first reported from this locality, exclusive of Miners River catches, in 1917, the year a cannery was first operated in the western part of the

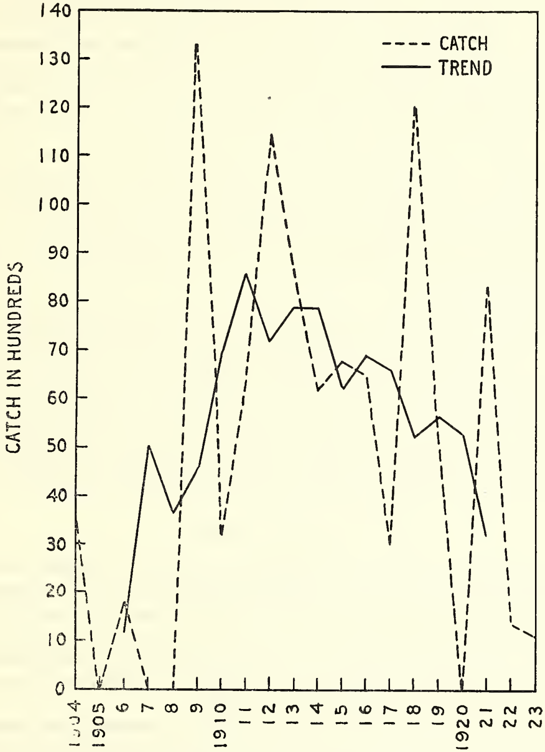

FIGURE 6.—Catch of red salmon at Miners River

sound. Apparently none was taken in 1918. In 1919, the catch in round figures was 6,500 chums, 7,800 pinks, and 3,200 reds. No catches were shown in 1920 and 1921 although a cannery was built and operated there in 1920. All catches by this company were reported, however, as merely coming from Prince William Sound. In the remaining six years, 1922 to 1927, the record appears to be complete, showing a large production of pinks, fair catches of chums in some years, and small yields of reds, cohos, and kings. Remarkable gains were made in the catch of pinks in the

even years from 1922 to 1926. Beginning with 104,140 in 1922 it rose in four years to the unparalleled total of 1,435,875 and made Unakwik Inlet one of the most productive localities of the sound. Even in the odd years, extraordinary gains were recorded as shown by a comparison of the catch of 88,134 in 1923 with that of 392,652 in 1927, emphasizing again the tendency toward equalization of pink-salmon runs in all years. No evidence of depletion is observed in this locality.

Wells Bay.—These data include a small catch made in 1927 at Fairmont. Situated just east of Unakwik Inlet and approached through the same entrance as the inlet, it might be supposed that, other things being equal, the runs of salmon to both localities would show no conspicuous differences in development, or that the locality which showed the larger catch when exploitation began in 1917 would continue to be the better field through succeeding years unless it had been overfished and the runs depleted. This however, has not been the case. When fishing began in this district, Wells Bay produced 15 times as many salmon as Unakwik Inlet, but in 1926, the year of exceptional runs on the sound, the inlet produced 54 times as many as the bay. From 1917 to 1924, the catch of both pinks and chums dropped with startling abruptness and then increased in 1925 only to be followed by another decline in the next two years. On the basis of available data, it may be assumed that the runs of both species at Wells Bay are seriously depleted. Other salmon have not been taken at this locality since 1922.

Disregarding the individual localities and considering Unakwik Inlet as a district, it would seem that, in so far as pinks and chums are concerned, conditions are satisfactory, and that reds are barely maintaining an even trend. Yet an examination of the data independently for each of the five localities leads clearly to the conclusion that the runs to Cedar Bay, Miners River, and Wells Bay are reduced to the danger point. The seriousness of the situation at Miners River was recognized in 1924. Immediately after the passage of the act of 1924 for the protection of the fisheries of Alaska, fishing in the vicinity of this stream was considerably restricted to give the red-salmon runs of that region a chance to rebuild themselves naturally.

GLACIER ISLAND DISTRICT

This district covers the coastal waters of the sound from Granite Point on the west to Point Freemantle on the east, including Glacier Island. Occasional catches were made outside of Long Bay which really harbors the only commercially valuable fishery of the district, but for purposes of this review, Billys Hole is considered separately because of its early exploitation. The unallocated catch in this district includes catches from Columbia Bay in 1917, from Granite Cove in 1922, and from Johnson Cove, probably intended for Jackson Cove, in 1927.

Billys Hole.—One of the oldest known red-salmon streams of the sound enters Long Bay from a small indentation on the west shore named Billys Hole. This place was fished as early as Miners River and Eshamy Creek, and before 1897 was rated as producing annually about 20,000 red salmon. No data are obtainable, however, showing the catches of salmon at Billys Hole until 1904. In that year, 3,000 reds were taken. In 1905, 1907, and 1908, catches were unallocated, but on the basis of its reputed value in 1897, it is probable that approximately 5,000 fish were caught in each of those years. An increasing yield from then until 1915 culminated in a catch of 15,775 in that year which marked the crest of a wave of production that then receded through successive years to 1924. The peak production of pinks was reached in 1917, that of chums in 1918, but thereafter the catch of both species followed the

decline of the reds. Billys Hole was closed to salmon fishing in 1924 and has remained closed ever since. The effect of this can not yet be ascertained.

Long Bay.—Records indicate that Long Bay, as distinguished from Billys Hole, was first fished in 1917 when 2,500 pink salmon, only, were taken. Fishing was not resumed until 1922, in which year a comparatively large number of pinks and a few thousand reds and chums were caught. In the next two years the catch of pinks and chums declined, while that of reds increased slightly. In 1925, reds declined but pinks and chums advanced. The catch of pinks was still larger in 1926, yet not equal to the catch of 1922. Reds and chums fell off. The catch of pinks in 1927 declined approximately 59 per cent which probably represented at that time the normal difference in runs of that species for even and odd years. More chums were taken than ever before, and the catch of reds again approached 3,000.

TOTAL, WESTERN PART

The development of the salmon fisheries in the western part of Prince William Sound was rapid. In a very few years after exploitation first began the district became an important producer, especially of pink salmon. This development is graphically shown in Table 5.

The general trend of the red-salmon catch has been downward since 1919; and yet at the end of 24 years of continuous fishing, the catches are approximately as great as during the early history of the fishery in spite of all the laws and regulations that have since been applied. Although some localities show reduced catches, others made larger yields and thus a general balance was maintained in that region. No material increase in the production of red salmon may be expected in this section as the streams used by this species are small, comparatively few, and largely of glacial origin, with low temperatures and probable limited capacity for the maintenance of the young salmon. Most of the streams of Prince William Sound are not lake fed, are relatively short, and produce chiefly the cheaper grades of salmon.

The pack of pink salmon has increased rapidly and steadily since the first catch was made in 1912. The abundance of pinks in this area was not even remotely realized until after several canneries were opened and commenced the regular exploitation of this fishery. The trend of the catch in both even and odd years ascended rapidly throughout the period covered by this report with the exception of a slight retardation during 1921 to 1923. There appears to be no indication of a diminishing supply of pinks.

Kings and cohos constitute minor fisheries of little value, though 1919 and 1920 show an unusual production of kings never approached before or since, and not explainable in the light of present data.

The catch of chums since 1916, the year in which that species was first reported, shows wide fluctuations, reaching its highest level in 1918 and its lowest in 1922, excepting 1921, when for economic reasons practically no fishing was carried on. Successively larger catches were noted in the next three years, 1923 to 1925, and since then remained fairly uniform. However, chums in the western part of the sound are not considered of great value and are taken chiefly incidental to other fishing operations.

TABLE 5.—*Graphic table showing the catch of salmon in the western part of Prince William Sound, 1904–1927*

[Each letter represents the following number of fish: Reds, 10,000; kings, 1,000; pinks, 200,000; chums, 10,000; and cohos, 10,000]

Year	Kings	Pinks	Cohos
1904	m		
1905			
1906			
1907			
1908			
1909			
1910			
1911			
1912		m	m
1913	m	m	m
1914		m	m
1915		m	
1916	m	mm	
1917	m	mmmm	m
1918	m	mmmmMmmm	mm
1919	mmmmMm	mm	mm
1920	mmmmM	mmmmMmmmmMmmmm	mmmmMm
1921		m	m
1922	m	mmmmMmmm	m
1923	m	mmmmMm	m
1924	mm	mmmmMmmmmMmmmmMmmmmMm	mmmm
1925	mm	mmmmMmmmmM	mmmmM
1926	mm	mmmmMmmmmMmmmmMmmmmMmmmmMmm	mmm
1927	mmm	mmmmMmmmmMmmmmMm	mmmmMmm

Year	Reds	Chums
1904	mmmmMmmmmMm	
1905	mmmmMmmmmM	
1906	mmmmMmm	
1907	mm	
1908	mmmmMmmmmMmm	
1909	mmmmMmmmmMmmmmMm	
1910	mmmmMmm	
1911	mmm	
1912	mmmmM	
1913	mmmmMmmm	
1914	mmmmMmmm	
1915	mmmmMm	
1916	mmmmMm	m
1917	mmmmMmmmmMmmmmMmmmm	mmmmMmmmmMmm
1918	mmmmMmmmmMmmmmMmmmmMm	mmmmMmmmmMmmmmMmmmmMmmmmMmmmm
1919	mmmmMmmmmMmm	mmmmMmmmmMmmmmMm
1920	mmmmMmmm	mmmmMmmmm
1921	mmmmMmmm	m
1922	mmmmMmmmmMmm	mm
1923	mmmmMmmmmMmmmm	mmmm
1924	mmmmMm	mmmmMmmm
1925	mmmmMmm	mmmmMmmmmMmmmmMmmmmMmmmm
1926	mmmmMmmmmMmm	mmmmMmmmmMmmmmMmmm
1927	mmmmMmmmmM	mmmmMmmmmMmmmmMmmm

EASTERN PART

For purposes of this review the eastern part of Prince William Sound is divided into four districts, each composed of several localities which have produced large numbers of salmon. The line which separates the eastern part from the western part extends from Point Freemantle to Montague Point, the northern extremity of Montague Island.

VALDEZ ARM DISTRICT

The Valdez Arm district extends from Point Freemantle on the west to Bidarka Point on the east, including Bligh Island. It embraces eight localities in which several thousand salmon have been produced over a period of years, and it holds second place in salmon production among the districts of the eastern part of the sound.

The following combinations of catches have been made: Valdez Arm includes small catches reported from Ellamar Bay in 1917, 1925, and 1927; catches from Lowe River in 1917 and from Robe Lake in 1917 and 1918 are added to those from Port Valdez.

Bligh Island.—Fairly large catches of all species of salmon were made at Bligh Island by traps in 1926 and 1927, but the data cover only two years and therefore afford no basis for analysis. Five times as many salmon were taken in 1926 as in 1927, thus showing a greater disparity in the catches for these two years than was noted in several of the western localities. This striking difference applies more particularly to pinks than to the other species.

Galena Bay.—This bay is a tributary of Valdez Arm, indenting the eastern shore of the mainland, and is fed by several small streams. Its fisheries are mainly pink and chum salmon, but occasional catches of the other species have been made. The record shows that fishing began here in 1917 and was continued through 1927, with the exception of 1921 and 1922. The catch of pinks was good in 1917, contrary to the rule that usually applies in odd years; in fact this catch has been exceeded only twice, and more interesting still, it represented 68 per cent of the entire production of pinks in the Valdez Arm district in that year. In general, however, the better runs occurred regularly in the even years although after 1923 the runs in the odd years perceptibly improved. Chum-salmon catches show an early peak in 1918 with reduced catches in subsequent years including 1921, 1922, and 1923. After this, catches increased to a high level in 1925, since when they have again dropped.

Jack Bay.—Jack Bay indents the eastern shore of Valdez Arm near Valdez Narrows. It was fished from 1917 to 1927, inclusive, with the exception of 1921 and 1922, the general history of the fishery being similar to that of Galena Bay. A very few red salmon were caught every year except 1923; kings were taken in one year, and cohos in three years. The catch of chums fluctuated considerably, reaching its lowest level in 1923 and its highest in 1927, which was slightly above the level of 1926. The catch of pinks has fluctuated widely. No catches were reported in 1921 and 1922, but after this interruption the catch has increased rapidly in both even and odd years. Nothing suggestive of depletion of pinks and chums at Jack Bay can be seen in the data here considered.

Lowe Point.—In 1920 a trap was located at this point on the north shore of Port Valdez east of Shoup Bay. It made a fairly large catch of pink salmon and smaller catches of the other species. The location was not used again until 1927, but the results were very different, as only a few thousand salmon were taken. These data are kept separate for future use, although at present they have no significance.

Potato Point.—This point, also the site of a fish trap, is located on the western shore of Valdez Narrows. Good catches of salmon have been made here. Except in 1921, when the trap probably was not driven, there should be an unbroken record of catches from 1920 to 1927, as operation of the trap was not prohibited in any of those years. The record is confused, however, for the reason that in some seasons the catch was reported as coming from Valdez Bay, or Port Valdez, instead of Potato Point, thus leaving no adequate data for analysis through a period of consecutive years.

Sawmill Bay.—A few miles west of Valdez Narrows on the northern shore of Valdez Arm is a small indentation known as Sawmill Bay. A seine fishery has been conducted there since 1917, with the exception of two years, 1921 and 1922, as noted in respect to several other localities. Scattered catches of coho, king, and red salmon

were made, but chums and pinks were taken in fair quantities. A trap operated at the mouth of the bay probably accounts for the better catch in 1920 and in subsequent years. During the earlier years of its operation, the trap was driven directly in the entrance of the bay, but in later years was moved to a point north of the entrance, and doubtless has taken salmon which were not strictly Sawmill Bay fish. Accepting the data as given and disregarding the years of 1921 to 1923 when the fishing effort was reduced, it is found that the catch of chums has declined markedly and gives rather positive evidence of a depleted fishery at Sawmill Bay. The pink-salmon catch fluctuated widely between 1920 and 1927, reaching the lowest level in 1924, a year that shows large production in other localities of the sound. It improved, however, in the next three years—a fact which indicates that the early apparent reduction in catch was not due to depletion but either to faulty data or variations in fishing intensity of which there is no record.

Valdez Arm.—Before 1923, comparatively few salmon were taken directly in Valdez Arm. Fishing was confined largely to the smaller bays. However, as traps came into general use, locations were established in the more open waters and profitably operated. Due to this change in the character of fishing and the probable incorrect allocation of catches, fairly large numbers of pinks were reported from the arm in 1924 and 1926, while the catch in 1925 was a complete failure. The trend of the pink-salmon catches in Valdez Arm proper seems to be downward, especially in the even years when the runs were universally heavy. On the other hand, chums were taken in larger numbers than ever before, and, though the catches were small by comparison, they show a steady upward trend, except for the poor catch recorded for 1925. The best catch of reds was made in 1920, the poorest in 1927. Kings are rarely taken in any number, while the catch of cohos was extremely variable.

Port Valdez.—The upper part of Valdez Arm, inside Valdez Narrows, is Port Valdez. At its head are several streams, all fed at least in part by glaciers. Robe River, the outlet of Robe Lake, carries less glacier water than the others and may be considered as the only tributary of the port that supports a run of red salmon. Although reds have been in general more abundant than any other species, the catch has declined quite steadily from 1917 to 1927. In 1924, the largest catch of pink and chum salmon ever made in Port Valdez was reported, due perhaps to the inclusion of the catch of the trap at Potato Point. This record year was followed by three years of poor catches. In general it is apparent that the catch of all species in Port Valdez was rapidly declining during the years just preceding 1927—the last year considered in this report.

Table 6 shows in graphic form the catch of the salmon fisheries of the Valdez Arm district. The curves for both cohos and chums are very similar, showing good catches during the early and late years with a period of poor catches between. So far as these data indicate, the productivity of the coho and chum fisheries of this district may be viewed with uncertainty in the next few years. The red-salmon fishery, centered mainly in Port Valdez, is undoubtedly failing. The supply of pinks alone appears to be unaffected, the catches becoming better in the odd years as well as in the even. King salmon do not constitute an important fishery, the largest catch being only 451 in 1923.

TABLE 6.—*Graphic table showing the catch of salmon in the Valdez Arm district of Prince William Sound 1917–1927*

[Each letter represents the following number of fish: Reds, 2,000; pinks, 50,000; chums, 10,000; cohos, 1,000]

Year	Reds	Pinks
1917	mmmmMmmmmM	mmmmMm
1918	mmmmMmmmmM	mmmmM
1919	mmmmMmmmmM	mm
1920	mmmmMmmmm	mmmmMmmmmMmmm
1921	mmmmMmmm	
1922	mmmmMmmmm	mmmmM
1923	mmmmMmmmmMm	mmm
1924	mmmmMmm	mmmmMmmmmMmmmmMmmmmMm
1925	mmmmMmm	mmmmMm
1926	mmmmMmm	mmmmMmmmmMmmmmMmmmmMmmmmMmmm
1927	mmmmMm	mmmmMmmm

Year	Chums	Cohos
1917	mmmmMm	mmmmMmmmmMm
1918	mmmmMmmmmMmmmmMmmmmM	mmmmMmmmmMmmmmMm
1919	mmmmMmmmm	mmmmMmmmmMm
1920	mmmmM	mm
1921	m	mmm
1922	mm	mm
1923	mm	m
1924	mmmmMmm	mm
1925	mmmmMmmmmMmmmmMm	mmmmMmm
1926	mmmmMmmmmMmmmmMm	mmmmM
1927	mmmmMmmmmMmm	mmm

PORT FIDALGO DISTRICT

This district covers the fisheries of the east coast of the sound from Bidarka Point southward to a point on the mainland approximately 1 mile north of Knowles Head, including Goose Island. Six localities are listed separately in this district in addition to Port Fidalgo itself.

Bidarka Point.—This point on the north side of the entrance to Port Fidalgo was occupied by a trap in 1919 and 1920 and again from 1925 to 1927, inclusive. The break in continuity of operations, covering a period of four years, 1921 to 1924, makes any attempt at analysis impossible. It appears probable from these meager statistics that relatively large numbers of pink salmon pass this point as the catch in 1926 was 221,361, and the catch in 1927 was also comparatively good. Fewer reds were taken in each successive year, chums fell off 50 per cent in two years, while the unimportant catch of cohos and kings was variable.

Port Fidalgo.—These data include catches reported from Boulder Bay in 1918 and 1925; from Goose Island in 1919, 1925, and 1927; from Landlocked Bay in 1917, 1918, 1919, 1925, and 1926; from Two Moon Bay in 1917 and 1918; and from Snug Corner Cove, which in turn includes Anchor Cove, in 1917 and 1927.

In the records of fishing in Prince William Sound from 1913 to 1927 are found many catches of salmon that were reported as coming from Port Fidalgo without reference to a stream or tributary bay. Part of these catches are accounted for in the operation of traps between Two Moon Bay and Snug Corner Cove and at the point on the east side of the entrance to Landlocked Bay. Some years were apparently good, others were poor. After 1924, fishing in Port Fidalgo was materially restricted by regulation, yet two of the largest catches in that locality were reported in 1926 and 1927, indicating that these fisheries have undergone no unfavorable change in a decade or more. The catches consist largely of pinks and chums with cohos next in importance and reds and kings negligible.

Fish Bay.—This small bay on the north side of Port Fidalgo has produced pink and chum salmon almost exclusively. The first pinks were taken in 1914, and catches were made in all succeeding years except 1916, 1920, and 1927. The catch was maintained at a fairly high level until 1919 when it suddenly dropped, due perhaps to economic conditions rather than biological causes. In 1923, it again reached a level comparable to that of preceding good years only to fall in 1924 to another extremely low figure, the reverse of conditions elsewhere in the sound where pink salmon are more abundant in even than in odd years. Another high point in production in 1925 was followed by a decline in 1926, yet the total for that year had been exceeded but twice in even years in this locality, 1914 and 1918. The catch in 1927 was again poor, only 1,374 pinks being taken. Chums were taken in increasing numbers from 1923 to 1925 but have since fallen off materially, due, perhaps, to an actual scarcity of fish rather than a change in the intensity of fishing. The catch of other species was too negligible for consideration.

Irish Cove.—Irish Cove is a small indentation on the south side of Port Fidalgo. It was fished intermittently from 1915 to 1923, producing at most a few thousand pink salmon. Since then no pinks have been caught in this locality. Cohos were taken in only three years, 1925 to 1927, the catch, though small, being progressively better in those years. The complete change of the fishery from pinks to cohos can not be explained at this time.

Porcupine Point.—This point marks the south side of the entrance to Port Fidalgo. In 1918, a trap was located there and made a catch of 217,026 salmon, predominantly pinks, though other species were rather evenly represented in proportion to the probable strength of the salmon runs to Prince William Sound. The suspension of operations from 1921 to 1923, inclusive, breaks the record of production, yet, upon resumption of fishing in 1924, little change in the fishery was evident as the total catch was 217,398, practically the same as was made six years earlier. The proportions were changed slightly as pinks had increased while the other species had declined. Because of the rather even catch by cycles, it is interesting to compare the totals for other years. The catch of all species in 1926 was 255,582, which is 38,184 more than that of 1924 when it was 217,398. In 1925, the total catch was 134,111 as against 135,737 in 1927—a difference of 1,626 in favor of the later year. A high degree of correlation at 2-year intervals is apparent in the catches for the last four years. The trend of the catch of both pinks and chums is apparently upward.

Sunny Bay.—This bay indents the north shore of Port Fidalgo between 146° 10′ and 146° 20′ west longitude. According to U. S. Coast and Geodetic Survey Chart No. 8550, it is unnamed, but locally it is known as Sunny Bay. Catch data are available for four years, 1919 and from 1923 to 1925, inclusive, showing that chums and pinks are the important species, with chums predominating. The total yield of all species for 1925 was 47,446, of which 63 per cent were chums, 36 per cent pinks, and 1 per cent cohos and reds. Fishing was not permitted in this bay at any time in 1926, and not after July 11 in 1927. Since it was primarily a chum-salmon district with a late run of fish, the close season became effective before any fishing could be done.

Whalen Bay.—On the southern shore of Port Fidalgo directly south of Sunny Bay is a short indentation known as Whalen Bay. Records show that it was fished 9 years in two periods of 4 and 5 years, respectively. The first period began in 1915 and ended in 1919 with no catch reported in 1916; the second, from 1923 to 1927. The catch consisted almost entirely of pinks and chums, fluctuating widely for both

species. The reduced yield in 1926 and 1927 presumably resulted from the closing order referred to in the discussion of Sunny Bay.

Viewing the Port Fidalgo district as a unit, it is obvious that pink salmon constitute its most valuable fishery resource. Other species are taken, chums leading but far below the level of the pinks. Table 7 gives a graphic picture of the salmon catches of the district down to 1927. The interesting feature is the upward trend in recent years for all species, particularly pinks. The small catch in 1922, following a year of no fishing, and the upset condition of trade in the salmon market from 1920 to 1924 were undoubtedly the causes of the reduced production for a few years beginning in 1919. It does not reflect the condition of the fisheries at the time but rather shows a material slackening of the fishing effort in that period to which may be due the larger runs of subsequent years.

TABLE 7.—*Graphic table showing the catch of salmon in the Port Fidalgo district of Prince William Sound, 1913–1927*

[Each letter represents the following number of fish: Reds, 1,000; pinks, 50,000; chums, 20,000; and cohos, 2,000]

Year	Reds	Pinks	Chums	Cohos
1913		mmm		
1914		mmm		
1915		mm		mmm
1916		mm		
1917	m	mmmmM	mmmm	mm
1918	mmmmMmm	mmmmMmmmmMmm	mmmmMmmmmM	mmmmMm
1919	mmm	mm	mmmm	mmmmMm
1920	mmmmMmmm	mmmmM	mm	mm
1921				
1922		m		
1923	m	mmm	m	
1924	mm	mmmmM	mmmmMm	mmm
1925	mmmmMm	mmmmMmm	mmmmMm	mmmmMm
1926	mmmmM	mmmmMmmmmMmmmmMmmmm	mmmm	mmmm
1927	mmmmM	mmmmMmmmm	mmmm	mmmmMmmmm

PORT GRAVINA AND ORCA BAY DISTRICT

This district includes all waters of the sound within a line from the southern boundary of Port Fidalgo district, described above, to a point 1 mile north of Shelter Bay on the west coast of Hinchinbrook Island, thence across the island to Point Steele on the east coast, and thence to Point Whitshed. Port Gravina and Orca Bay with their tributaries are by far the largest producers of pink, chum, and coho salmon of all the districts of Prince William Sound. Sixteen localities of recognized importance are found in the district. The following combinations were made in preparing the tables: Orca Bay includes catches reported from Orca Inlet in 1925, 1926, and 1927; from Government Rock in 1924, from Hinchinbrook Island in 1917, 1926, and 1927; from Hawkins Island in 1912 and 1916; from Nelsons Lagoon in 1917; and from Sheep Point in 1925. Port Gravina includes catches reported from Hell Fire Creek in 1914; from Bear Cove in 1915; from Toms Bay in 1914, 1915, and 1916; from Comfort Cove in 1915, 1917, and 1918; from Gravina Island in 1918; from Hells Hole in 1917 and 1918; from Devils Cove in 1918; from Tom Thumb Bay in 1918; and from Red Head in 1927. Anderson Bay includes a catch from Big Fred Bay in 1917; Simpson Bay, a catch from Bomb Point in 1927; and St. Matthew Bay, catches from Black Bay in 1915, 1916, 1918, and 1922.

Anderson Bay.—Two bays indent the north coast of Hinchinbrook Island, the westernmost being Anderson Bay. Pink salmon only were taken here in 1917, the year fishing began, but in 1918 all species except kings were taken, although there

was little difference in the total number of salmon caught. That marked the end of fishing until 1923, when the total catch was 2,784 pinks and chums. In 1924, however, the catch jumped to 228,777 pinks, 26,470 chums, and a few reds and cohos. The catch fell off again in 1925, increased again in 1926, and went still higher in 1927, yet did not even then equal the total of 1924, though the number of chums and cohos was larger than in any other year. Special mention should be made of the unusual catch of cohos in 1927, when 41,722 were reported by a single company. This catch was larger by several thousand than that of any other locality of the sound in any year and is wholly at variance with all earlier records, as the entire catch of cohos in Anderson Bay from 1917 to 1926, inclusive, was only 17. If this catch was correctly reported, it was made by a trap on the north shore of Hinchinbrook Island outside of Anderson Bay and came from the runs of cohos to the streams of the mainland on the north side of Orca Bay, or to Copper River. It is probable that this trap was operated later in the year than others in the same locality. Reds and kings have not been taken in appreciable numbers.

Bear Trap Bay.—This bay is a small indentation on the eastern shore near the head of Port Gravina. Data for six years show that the first catch was made here in 1915 and consisted of 13,725 pink salmon. In 1917 the bay was again fished and produced 22,439 salmon, of which 20,000 were pinks. It was then abandoned until 1923, but the catch in that year was barely 2,000 pinks and chums. No catch was reported in 1924. From 1925 to 1927, fishing was carried on each year with wide fluctuations in catch. The stream near the entrance of the bay is blocked 600 feet above its mouth by a high falls; and the streams at the head of the bay are short and extremely precipitous, providing only a small area for spawning. In the nature of things, Bear Trap Bay is not likely ever to be a large producer of salmon.

Canoe Passage.—Canoe Passage is a narrow, shallow waterway dividing Hawkins Island into two almost equal parts. Salmon in small numbers may use streams tributary to the passage, but in all probability the greater part of the catch from this locality was taken at the Orca entrance from runs passing along the coast to streams of the mainland. Pinks and chums and a few reds were caught here, the largest catch being 120,863 in 1926, almost five times as many as were captured in any other year. The passage gives no promise of developing a larger fishery than now exists.

Double Bay.—This name is frequently applied to two bays which indent the north shore of Hinchinbrook Island, but in this review it designates the easternmost bay between Hawkins Cut-off and Johnstone Point, the western one being Anderson Bay. Data are few and represent small catches for three years only, 1925 to 1927. Pinks and chums were taken, the best year being 1926.

Gravina Point.—Gravina Point is the end of the peninsula between Port Gravina and Orca Bay. Except in 1921 and 1923, catches were reported from this locality from 1918 through 1926. The largest catch of pink salmon at any locality in Prince William Sound, except Unakwik Inlet, was made at Gravina Point in 1924, nearly 900,000 being taken. Before that year catches were comparatively small and were composed

largely of pink salmon, although the other species were represented in most years. Traps accounted for practically the entire catch at Gravina Point which is merely a section of the cost where the runs, in good years, approach the shore in greater numbers than elsewhere. Certainly the presence of large numbers of salmon at this point is not induced by streams in the immediate locality, for there is none suitable for the use of spawning salmon. The obvious explanation is that salmon follow a migration route which brings them to the shore here and traps effectually intercept their passage, whether into Port Gravina or Orca Bay.

Hawkins Cut-off.—Hawkins Cut-off is the passage which separates Hawkins Island from Hinchinbrook Island. Several small salmon streams flow into it which in the aggregate support fair runs of pink and chum salmon while cohos are fairly numerous. Reds and kings are taken in negligible quantities. The Cut-off may also be a passageway for salmon entering the sound. Disregarding the insignificant catch of reds and kings in 1917, fishing in the Cut-off began in earnest in 1918 and resulted in a catch of 227,000 pinks, 35,000 chums, and 1,000 cohos. Thereafter, until 1924, considerable variation in the catch was noted from year to year, while in two years, 1921 and 1923, there was no catch at all. Fishing improved materially from 1925 to 1927 for pinks, chums, and cohos and with no indication of depletion of the runs.

Johnstone Point.—This point is on the northern shore of Hinchinbrook Island. If available data are reliable, fishing was carried on there irregularly from 1917 to 1922, the catch consisting largely of pink salmon. In 1924, after the new law became effective and a more exact allocation of catches was required, a decided change in the catches referred to this fishery was observed. In 1922, the last preceding year, the entire catch at this point was reported as 6,072 pink salmon; but the catch in 1924 was 394,431 pinks and 12,304 chums, and from then on the records are quite complete, showing large catches for each season through 1927 and a marked upward trend in respect to pink salmon especially.

Knowles Head.—The southern extremity of the peninsula between Port Fidalgo and Port Gravina is known as Knowles Head. The first catch of salmon was made at this point in 1918; though small, it was composed of all species, reds constituting about two-thirds of the total number. In 1919 a trap was driven at the point, making a much larger catch, with pinks predominating. Fishing was continued each year thereafter through 1927, except 1921. Catches of all species, except kings, were consistently good without conspicuous evidence of a falling trend. This is probably due to the fact that Knowles Head is a point where the runs of salmon seem to strike the shore before they are dispersed to the several streams of the eastern part of the sound. For that reason the catches at Knowles Head may continue to be relatively large unless there is a general failure of the runs.

Makaka Point.—This point is on the north coast of Hawkins Island near the north entrance of Hawkins Cut-off. It was fished in 1915, but the catches in that year, and in 1917 and 1918 when it was again fished, were small. For five years, 1919 to 1923, no fish were reported from this locality. Beginning in 1924 and continuing through 1927, better catches, mainly pinks, were made with the totals for 1927, an odd year, far in excess of those for any other season. Pink-salmon catches have increased rapidly in the latter years, indicating a change in the method of the fishery (or possibly in the movement of salmon). Such a marked increase was not shown at any other locality in the Port Gravina and Orca Bay district and its real significance is not known at this time.

Olsen Bay.—Olsen Bay is a small indentation on the north side of Port Gravina. Fishing for pink and chum salmon was probably begun here as early as at several other localities in the eastern part of Prince William Sound, but no separate record of catches was kept until 1918. In that year 28,132 chums and 79,341 pinks were caught. The catch was small in 1919 and there is no record at all of catches made during the next three years. From 1923 to 1927 data are available for each year, showing that the production of pinks in the odd years declined sharply while little change was noted in the even years. Chums were taken in larger numbers in 1925 than before or since, but the data are insufficient to warrant a conclusion in respect to the condition of this fishery. Other species are taken in such limited quantities as to be commercially valueless.

Orca Bay.—In area Orca Bay is the largest indentation on the east side of Prince William Sound. Little fishing was carried on directly in the bay which could not be or was not allocated to more localized waters; but in some years, especially in 1916 and 1926, rather large catches were reported only as coming from Orca Bay. However the records are seriously broken by gaps of from one to seven years, thus giving no data by consecutive years for analysis.

Port Gravina.—Port Gravina is the next bay north of Orca Bay. It has five small tributary bays and in addition is fed by one stream of fair size, entering at the head of the bay. Port Gravina was one of the first districts in the sound to be exploited, owing to the proximity of the canneries at Cordova, and operations have been much more continuous here than in many other localities. The catch consisted largely of pink salmon, although cohos and chums were taken in fair quantities. Wide fluctuations in the catch of pinks are apparent, some of which can be traced to economic conditions while others were doubtless due to biological causes as evidenced by the poor runs in certain years. More coho salmon were taken in 1927 than ever before; the catch of chums in the same year had been exceeded but twice, and then only in the years when fishing was most intense. The catch of pinks in 1927 was likewise better than in any other odd years except 1907, 1913, and 1915. As a producer of pinks, cohos, and chums Port Gravina seems to have maintained a good record and shows no indication that the runs have been impaired.

Sheep Bay.—Sheep Bay, the largest arm of Orca Bay, produces principally pinks and chums although there have been small scattered catches of all other species. It was fished each year from 1910 to 1927 except two—1919 and 1921. In the earlier years the catch of pinks varied markedly, irrespective of odd or even years, but since 1922 it has reached and held a much higher level, with 1927 showing not alone the largest production of pinks but also the greatest number of cohos and chums ever taken from that locality. The trend of the catch for these species is distinctly upward.

Simpson Bay.—Simpson Bay, also an arm of Orca Bay, is divided into two arms, the eastern one being the preferred seining ground. Fishing was apparently spasmodic until 1923, although the largest catch in this bay was reported in 1907. In the five years from 1923 to 1927 the catch of pink salmon twice exceeded 100,000, but in 1925 it was less than 10,000. The catches of chums and cohos during this period have also increased. Reds are taken in very limited numbers and kings not at all. The data indicate a marked increase in the intensity of fishing in recent years but so far without depletion.

St. Matthew Bay.—This bay is the largest arm on the north side of Port Gravina. From 1915, the year in which the first catch was reported from this place, until 1927, a period of 13 years, catch records are lacking for four years. No catch from this bay was reported for 1926 which was the banner year in practically all other localities of the sound. This lack is undoubtedly due to faulty data since 486,984 pink salmon were taken in 1924 in St. Matthew Bay. It is probable that salmon caught in this locality were credited either to Port Gravina, Orca Bay, or to Prince William Sound indiscriminately. As noted elsewhere the pink-salmon fishery is appreciably improving in the odd years. Data for other species are not sufficient to warrant detailed consideration

Windy Bay.—Windy Bay indents the north shore of Hawkins Island just east of the one hundred and forty-sixth meridian of west longitude. Available statistics show that fishing began here in 1910 and was carried on irregularly through 1927. Red and coho salmon were taken infrequently; chums were obtained to the extent of a few thousand in 1918 and again from 1924 to 1927, inclusive; and pinks in each year shown. The pink-salmon fishery is therefore the only commercially important one at Windy Bay. The catch has fluctuated some but after 18 years is apparently at almost the same level that was reached in 1910. No evidence of depletion is apparent.

TABLE 8.—*Graphic table showing the catch of red, pink, chum, and coho salmon in the Port Gravina and Orca Bay district, 1904–1927*

[Each letter represents the following number of fish: Reds, 1,000; pinks, 100,000; chums, 10,000; and cohos, 5,000]

Year	Reds	Pinks
1904		m
1905		
1906		
1907		mmm
1908		m
1909		
1910		mm
1911		mm
1912	mm	mmmm
1913	m	mmm
1914		m
1915	m	mmmm
1916		mmmmMmmm
1917	mmm	mm
1918	mmmmMmmmmMmmm	mmmmMmmmm
1919	mmmmMm	mm
1920	mmmmMmmmmMmmm	mmmm
1921		
1922	mmmmMm	mmmmMmm
1923	mmmmMmmmmMmm	mmmmM
1924	mmmmMmmmm	mmmmMmmmmMmmmmMmmmmMmmmmMmmmmM
1925	mmmmMmm	mmmmMmmmmMm
1926	mmmmMmmmmMmmmmMmmmm	mmmmMmmmmMmmmmMmmmmMmmmmMmmmm
1927	mmmmMmmmm	mmmmMmmmmMmmmmM

Year	Chums	Cohos
1910		mmm
1911		mmmmM
1912	m	mmm
1913	m	
1914		mmm
1915	m	m
1916	m	
1917	m	mmm
1918	mmmmMmmmmMmmmmMmm	mmm
1919	mmmmMmmm	mmmmM
1920	mmmm	mmmm
1921		mm
1922	mm	mm
1923	mm	mm
1924	mmmmMmmmmMmmmm	mmmmMm
1925	mmmmMmmmmMmmmmMmmmmMm	mmmm
1926	mmmmMmmmmMmm	mmmm
1927	mmmmMmmmmMmmmmMmmmmMmm	mmmmMmmmmMmmmmMmmmm

Table 8 gives a graphic picture of the catch of cohos, chums, pinks, and reds in the Port Gravina and Orca Bay district. Kings are not shown as the catches were comparatively insignificant. The peaks in production of pinks in 1916 and 1918 are directly traceable to the opening of several new canneries at that time. The low levels of the next few years, 1919 to 1923, were caused chiefly by the lighter runs of salmon in 1919 and the overproduction in 1920, resulting in a large surplus of canned salmon and a collapse of the market for pinks. By 1923 operations were again normal. Vastly higher peaks of production than ever before attained were reached in 1924 and 1926, while in 1925 and 1927, regarded as off years, the catch was far above the peaks of 1916 and 1918. The coho and chum fisheries also show larger returns in late years and an upward trend of the catch since 1921. In general, this is true of the red-salmon fishery, the largest catch in the history of the district being made in 1926.

HINCHINBROOK ENTRANCE DISTRICT

This district covers the waters of the western coast of Hinchinbrook Island from 1 mile north of Shelter Bay to Cape Hinchinbrook and the eastern coast of Montague Island from Montague Point to Cape Cleare. It embraces five localities which are treated separately in the statistical table, but as all of them except Port Etches were fished very irregularly before 1925 the data are too few for analysis. Catch records at Port Etches, which includes Constantine Harbor, are available for 10 years, though somewhat disconnected, and include catches reported from Chiefs Bay in 1913, from Constantine Harbor in 1927, from English Bay in 1918, from Garden Cove in 1923, from Nuchek (sometimes called Nutchek) in 1914 and 1917. The record for Zaikof Bay includes a catch reported in 1917 from "Kaikoff" Bay which was probably intended for Zaikof Bay. The unallocated catches in this district include salmon reported from Bear Cape in 1918 and 1927, from Seven Sisters in 1927, and from Wahnya Bay in 1917.

The first catch recorded at Port Etches was in 1913 and consisted entirely of pink salmon; in 1914, only a few hundred cohos were taken. Nothing more was done until 1917 in which year fishing was resumed and carried on for four years without interruption. The next catch was recorded in 1923, but there is no record of a catch in 1924. From 1925 to 1927 the record appears to be complete and shows a marked increase in the catch of all species, 1927 being an exceptionally good year for pinks in spite of the fact that closed areas for a mile or more were established off the mouth of the main tributary stream of Constantine Harbor and the one at the head of Port Etches.

The other localities which form this district are: Anchor Bay, a small indentation on the west coast of Hinchinbrook Island about 3 miles north of Bear Cape; Rocky Bay and Zaikof Bay on the north end of Montague Island; and Shelter Bay on the west coast of Hinchinbrook Island. Zaikof Bay is the most important of these localities and produced a catch of nearly 150,000 pink salmon in 1926.

TOTAL, EASTERN PART

The statistical history of the eastern part of Prince William Sound, taken as a whole, goes back much farther than the history of any one of its minor localities; but the early figures can not be taken without reservation as the catches of the sound and of the Copper River were inextricably mixed in the records. Moser's reports of 1899 and 1902 and the various reports of the Treasury agents give data on these fisheries back as far as 1889. The chief fishery in those days was for the red salmon of the Copper River; but the canneries were located on the eastern edge of Prince William Sound, after the first three or four years, and it is quite apparent from an examination of the data that allocation of catches as between the two districts was by no means accurately made. The data are otherwise confused also as, for instance, in the Treasury report on the salmon fisheries in Alaska for 1896, Tingle gives statistics of the salmon pack for only one of the two canneries that were operating in the sound in that year. In these he gives the catch of cohos as 219,073, a figure which is quite beyond belief and is, furthermore, exactly the sum of the catches of pinks and cohos as given by Moser (1899, p. 30) for the same company mentioned by Tingle (the Pacific Packing Co.). It seems quite certain, therefore, that Tingle's figure for the coho catch is in error. Moser's figures are undoubtedly much better but are given in detail for only two years so that it is impossible to determine what the catches by species actually were for the period previous to 1904 when the collection of data was begun by the Bureau of Fisheries. In view of these conditions it has seemed best not to attempt any arbitrary allocation but to give the data as they stand in the old records in a separate table. Because the more important elements of the catch in those days derived from the Copper River, the table will be found in the section dealing with the fisheries of that district. In compiling this table Moser's figures have been used for the years 1896 and 1897 and those given in the Treasury reports for the other years. Although there is no way in which the recorded catches can be accurately allocated, it is probable that the pinks were secured mainly in the eastern part of the sound and that some, at least, of the cohos (if indeed the fish recorded as cohos were actually of this species) came also from this district. Some of the red salmon were doubtless taken in the western part of the sound.

The table shows clearly that this section of the sound, from 1904 to 1914, inclusive, produced little else than pink salmon and that the largest catch of this species, 573,967, was made in 1904. It also shows that no salmon were caught in this region in 1905, 1906, and 1909 due in all probability to the allocation of catches in those years to the streams of the Copper River delta. During much of this period the field was fished by a single cannery at Orca; and the fishing effort remained almost constant, to which fact is undoubtedly due the rather uniform catch for many years. The fisheries of the eastern part of Prince William Sound since 1910 are shown graphically in Table 9. In 1916, the intensity of fishing changed abruptly with the establishment of more canneries, and the catch of all species of salmon except kings surpassed all previous records—five times more pinks being taken than ever before. Chums and reds, previously taken in small numbers, showed an even higher ratio of increase. The subsequent years, 1921 alone excepted, produced generally much larger catches of all species but there appears to be no indication of any material change or prospect of change in abundance in the near future. Some localities, as has been shown above, show reduced catches, but these are more than counterbalanced by increased catches in other places. It must be borne in mind, of course,

that many of these details may be erroneous due to faulty and incomplete data. The trend of the catches in the Valdez Arm district is upward for cohos, chums, and pinks, while in the other districts, it is upward for all species. Thus at the end of 1927, the fisheries of the eastern part of Prince William Sound, taken as a whole, were apparently never in more flourishing condition, and had never reached a higher level of productivity.

TABLE 9.—*Graphic table showing the catch of salmon in the eastern part of Prince William Sound, 1910–1927*

[Each letter represents the following number of fish: Reds, 10,000; kings, 200; pinks, 250,000; chums, 50,000; and cohos, 10,000]

Year	Reds	Kings	Pinks
1910			m
1911			m
1912	m		mm
1913	m	mmm	mm
1914			m
1915	m		mm
1916	mmm		mmmmMmmmmMmm
1917	mmmm	mm	mmmmMmmm
1918	mmmmM	mmm	mmmmMmmmmMmm
1919	mmmm	mmmmMmmmm	mmm
1920	mmmmMm	mmmmMmmmmMmm	mmmmMmmmmMm
1921	mm		m
1922	mmm	mm	mmmm
1923	mmmm	mmm	mmmmMm
1924	mmmmMmmmmMm	mm	mmmmMmmmmMmmmmMmmm
1925	mmmm	mmmmMmmmm	mmmmMmmmm
1926	mmmm	mmmm	mmmmMmmmmMmmmmMmmmmMmmmm
1927	mmm	mmm	mmmmMmmmmMmm

Year	Chums	Cohos
1910		mm
1911		mmm
1912	m	mm
1913	m	
1914		mm
1915	m	m
1916	m	mmmmM
1917	mmmmMm	mmmmM
1918	mmmmMmmmmMmmmmMmmmmMmm	mmmmmMmmm
1919	mmmmMmmmm	mmmmmM
1920	mmmm	mmmm
1921	m	m
1922	m	m
1923	mm	mm
1924	mmmmMmm	mmmm
1925	mmmmMmmmmMmm	mmmmM
1926	mmmmMmmmm	mmmmmM
1927	mmmmMmmmmM	mmmmMmmmmMmmmmMmmmmM

TOTAL, PRINCE WILLIAM SOUND

The unallocated catch of Prince William Sound includes salmon reported from Seward Bay in 1922; from Cape Horn in 1922 and 1923; from King Salmon Bay in 1913, 1919, and 1923; from One Bay, Port Mole, Starboard Inlet, Unimack Bay, and Yackat Bay in 1917; from Sea Bay in 1918; and from Mine Bay in 1919. None of these localities could be located.

Prince William Sound is not a large producer of red salmon. The catch of this species from 1904 to 1927 is shown graphically in Figure 7. Wide and fairly regular fluctuations in the catches from year to year are apparent in this graph, but these fluctuations are not clearly periodic. This would, of course, be expected in a district where the catches are made up of fish belonging to a number of races no one of which dominates the situation in the district as a whole. The catches in some of the localities listed in the table are not necessarily related to any particular stream as several of the localities are merely points on the shore where traps intercepted salmon bound

elsewhere. In fact, outside of Eshamy Creek, Jackpot Bay, Miners River, and Billys Hole no red salmon were taken in the western part of the sound before 1917. Between 1914 and 1917 the number of canneries increased from 1 to 9 and the fishing effort was materially augmented. This development of the fishery disclosed the presence of red salmon in places not previously known to support runs of that species. Except in Valdez Arm, however, these catches of reds were not in sufficient numbers to have much significance. Still, it must be recognized that the distribution of red salmon in the sound regardless of the character of the streams in the several localities was very general. It is also interesting to note that notwithstanding the permanent

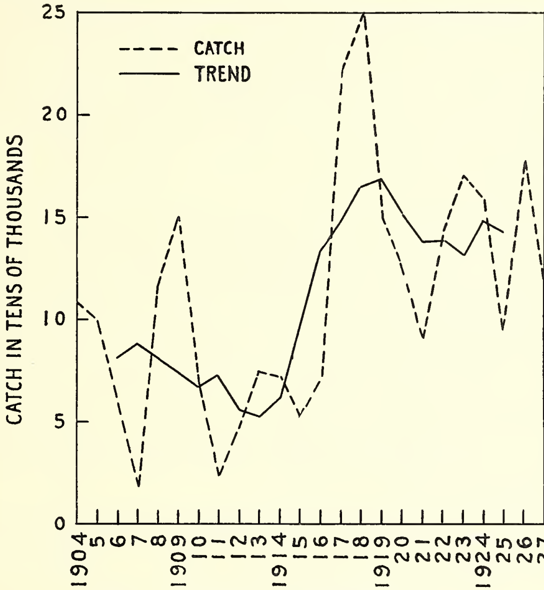

FIGURE 7.—Catch of red salmon in Prince William Sound

closing, in June, 1924, of the waters close to the better-known red-salmon streams, the average annual catch of reds in the four years from 1924 to 1927 was only about 10 per cent below the average for the eight years from 1916 to 1923.

It is also true that as the number of canneries increased the number of fishing appliances was multiplied several times. Beach seines increased from 9 in 1916 to 48 in 1917, purse seines from 21 to 49, gill nets from 19 to 69, and traps from none to 3. In the next three years progressively more appliances were put into operation, except seines which reached their maximum in 1918, until in 1920 the number of beach seines was 54, purse seines 63, gill nets 217, and traps 47. This was the period during which practically all regulations were set aside in order that large packs might be made for war-time food purposes. Intensive fishing resulted and the exploitation of the

fisheries was carried far beyond the development of earlier years. Then followed the postwar depression and the reduction of fishing activity which culminated in the practical abandonment of the fisheries in Prince William Sound in 1921 for all species except reds. With the beginning of economic readjustment in 1922, packing plants were reopened and fishing appliances again began to increase, so that by 1927, 12 canneries were packing salmon from the sound, and 6 beach seines, 95 purse seines, 8 gill nets, and 64 traps were used in making the catch. While the average catch of red salmon in the four years from 1924 to 1927 was fairly close to the average of the eight years immediately preceding, as already noted, it is undoubtedly true that the catch was maintained only by the greater fishing effort. From these facts it is quite apparent that the production of red salmon in Prince William Sound will never be large, due to the limitations of the areas available as spawning grounds, and that the yield of nearly 250,000 in 1918 probably represents the maximum productivity of reds in this district. Although the total catch figures show no marked depletion this is unquestionably due, at least in part, to the gradual spread of the fishery and consequent exploitation of new red-salmon resources. It seems probable that certain of the red-salmon runs have been depleted but that the present regulations will prevent further depletion.

The first recorded catch of pink salmon in Prince William Sound was made in 1896. Beginning then and continuing through 20 years, including 1915, the catch was very uniform, only once exceeding 500,000, while the average yield was close to 300,000. No catch at all was reported in 1905, 1906, and 1909. It is also noteworthy that before 1916 nearly the entire catch of pink salmon in this district came from the bays of the eastern part of the sound. Up to that time the rather weak market for pinks was adequately supplied by the canneries in southeastern Alaska and there was no inducement to pack them in the western districts where operating expenses were considerably higher. However, under changing conditions and the stress of war, the market for pinks was stimulated and in the next few years after 1915 the number of canneries on Prince William Sound increased rapidly, primarily to pack this heretofore neglected species. Eventually 15 canneries were operating here and the catch increased amazingly and quite steadily for 12 years; and this in a district which had been rated as exceptionally poor in salmon resources.

Pink salmon are widely distributed in the sound and enter practically every stream in the district. With few exceptions, the localities first to be fished have maintained a fairly even supply, while newer places, those that were not exploited before 1920, became, in a few seasons, the largest producers of the sound. The west coast of Montague Island is a striking illustration of this fact, as not until after 1919 were large catches reported from that shore, and they were due entirely to the operation of traps in those waters. Tagging experiments conducted in 1929[6] indicate that salmon taken here do not come predominantly from runs destined to streams of Montague Island, but rather that Montague Strait is the favored passage through which salmon enter the sound and then disperse to all localities. No catch has ever been reported from the eastern shore of Montague Island, but the northeast coast of Montague and the western shore of Hinchinbrook Island have produced catches of salmon which presumably came from runs entering the sound through Hinchinbrook Entrance but which by no means equal the runs entering Montague Strait.

A graphic picture of the catch of pink salmon in Prince William Sound is shown in Figure 8. Since 1915, it is clear that there have been heavy runs on the even years

[6] Thomson, loc. cit.

and smaller runs on the odd years, a phenomenon which has been observed repeatedly in other districts. Another fact of interest is that in 1921 the smallest catch of record in the sound was made, but it was not indicative of the size of the run in that year as no effort was made to take pinks owing to the depressed condition of the market from which recovery was only partial in 1922 and 1923. Disregarding these three years, the graph shows a strong upward trend of the fishery throughout the period 1915 to 1927, both good and lean years becoming steadily better. Even the odd year of 1927 was better by several hundred thousand salmon than any of the even years except 1924 and 1926. This increase in the catches of pinks in the odd year was quite

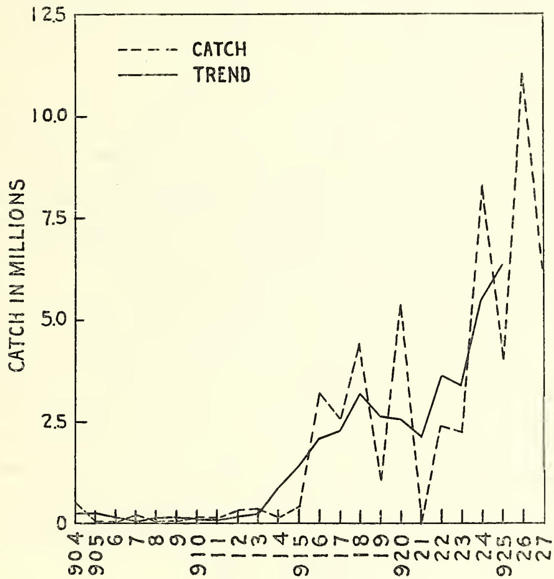

FIGURE 8.—Catch of pink salmon in Prince William Sound

general over a large part of Prince William Sound and in other districts to the westward as noted in Part II of this review. The increase in the catch in 1927 was unquestionably due to an increase in the actual abundance of fish and was thus due to biological rather than economic causes. Just what these causes were is unknown but it was suggested in Part II that they may have been associated with the unusually mild winter of 1925–26.

The coho salmon fisheries of Prince William Sound were possibly the first to be exploited, dating back to 1893, when development of the Copper River fisheries was begun. In the records from 1893 to 1900 (see table 10), it seems very probable that the reported catches of cohos in some years were composed largely of pinks. This supposition rests primarily upon the fact that from 1901 to 1909, a period of 9 years, no

cohos were reported from the sound. Casual development of the coho fishery began in 1910, as incidental to fishing for reds and pinks rather than as an independent fishery, and since then catches have been reported each year, wide fluctuations occurring at irregular intervals, indicating either poor runs, or lack of fishing effort. In 1913, 406 cohos were taken, of which 383 came from Eshamy Lagoon and the remaining 23 from Bay of Isles. This small catch is rather convincing evidence that in 1913, at least, no effort was made to take cohos anywhere in the sound, such catches as were made coming as the direct result of fishing at certain localities for reds and pinks, without any attempt to fish the runs of cohos in other localities where reds and pinks were not commercially obtainable. The real development of this fishery dates from 1916, and it gained proportionally with the increase in the number of canneries until in 1918 the catch totaled 100,247. In 1921 and 1922 catches were small, due to reduced fishing effort, but thereafter they increased rapidly and reached a total of 258,816 in 1927—the highest yield of cohos on record in the sound up to that time. In this connection it is interesting to note that the western part of the sound is in general a poor coho district; and that in the years of largest catches, traps on the west coast of Montague Island produced a large percentage of the total from that section. Seining in the bays is relatively much less productive of this species. This fact may indicate that cohos bound for streams in the eastern part of the sound enter through Montague Strait although it is possible that many are bound for Copper River and other streams in that region and have only entered Montague Strait en route. There is no evidence of depletion of the coho runs as the low production from 1921 to 1923 was certainly due not to scarcity of fish but rather to overproduction in the years just preceding.

The first reported catch of chums was made in 1912 and amounted to only a few hundred fish. The catch in the next three years was also insignificant, but in 1916 nearly 46,000 were taken. Thereafter, the catch was measured by hundreds of thousands (except in 1921 and 1922) reaching a total of 1,341,887 in 1918, while in four subsequent years it exceeded a half million fish. Roughly estimated, four-fifths of the entire chum catch came from the eastern part of the sound, though there was a far more general distribution of this species than there was of cohos. It is a fishery of comparatively recent exploitation, having been developed since 1916 along with the introduction of traps in the sound until in 1927 it ranked next to pinks in quantity of production. Chums were apparently fairly abundant in every year that a real effort has been made to catch them, and the fishery, at least through 1927, shows no sign of depletion.

COPPER RIVER

Several rivers flow into the ocean from the Pacific slope of Alaska between Point Whitshed at the eastern entrance of Prince William Sound and Point Martin, some 45 miles to the eastward. They are, from west to east, Eyak, Glacier, Copper, and Martin Rivers, the most important one being the Copper. Together they constitute with the adjacent coastal waters, what is here called the Copper River district. (See fig. 9.)

Copper River is the largest salmon stream of the southern coast of Alaska and with its many tributaries drains a large area in the south central part of Alaska where glaciers supply much of the water which eventually reaches the ocean through its channels. Due to this large quantity of glacial water, Copper River is a very muddy

stream through the summer months and is noticeably cloudy in the other seasons. Not all of its tributaries are discolored, however, as several clear streams form the headwaters of the rivers draining the Copper River basin. The entire river system abounds in lakes, many of which are more or less turbid, due to the action of galciers, yet in all this elaborate network of streams and lakes, favorable spawning grounds are comparatively limited and aggregate much less than in many smaller streams in other parts of the territory.

Through much of its length, the Copper is a swiftly flowing river heavily loaded with silt which is deposited at its mouth. In the course of years, a large delta has

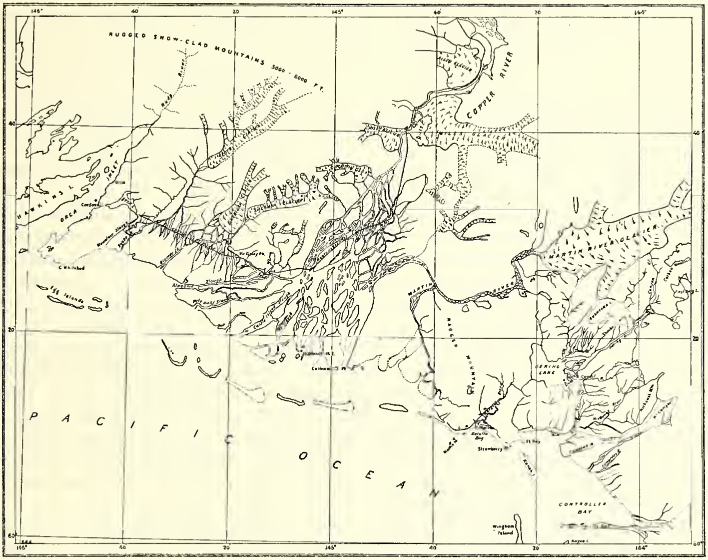

FIGURE 9.—Map of the Copper River and Bering River districts

thus been formed, spreading completely between the east and west boundaries of the district, while large quantities of silt have been swept into the eastern part of Prince William Sound through Orca Inlet. Conspicuous sand bars have also been formed across this stretch of coast about 4 miles out from the edge of the delta, giving further proof of the tremendous quantity of solid material being constantly brought down by the river. Through the delta thus formed, the river has maintained several channels in addition to the main outlet just west of Cottonwood Point. These channels, or sloughs as they are commonly called, and the mud flats between the sand bars and the delta, have been the principal fishing grounds in the Copper River district ever since exploitation of its runs of salmon began.

The river, notwithstanding its size and ramifications, is only a moderate producer of salmon, though its kings and reds are unsurpassed in quality anywhere in Alaska and always command a good price. These two factors, more than anything else, led early to a steady expliotation of the runs of kings and reds which threatened destruction of this valuable fishery.

Commercial fishing in Copper River began in 1889 with the establishment of two canneries on Wingham Island off the entrance to Controller Bay and two at Odiak, a bight on the north side of Orca Inlet nearest the southwest head of Eyak Lake. The plants on Wingham Island drew their salmon mainly from Copper and Martin Rivers, while those at Odiak obtained their supply almost entirely from Eyak Lake or the western part of the delta. In 1890, one cannery on Wingham Island was moved to Thin Point in western Alaska near the end of the peninsula; the other was moved to Kokinhenik Island directly in the mouth of Copper River in 1891 and continued to operate there until 1897 when it was permanently closed and dismantled. One cannery at Odiak operated until 1905 and was then sold to the Copper River & Northwestern Railway Co. which used it for other purposes; the second plant was moved in 1895 to Orca, a point on Orca Inlet about 4 miles west of Odiak and was operated each season thereafter through 1918. The Orca cannery was closed in 1919 and had not been reopened as late as 1927, though for nine years, 1906 to 1914, it had been the only cannery between Yakutat Bay and Cook Inlet and had undisputed possession of the entire field aside from the competition of a few salteries on Prince William Sound and a mild-curing station on Copper River just north of Abercrombie Canyon. Beginning in 1915 with the establishment of a cannery at Mile 55 on the Copper River & Northwestern Railway and one at Cordova, radical changes in the character of the fishery were inaugurated and there was then set in motion a new order of things which soon developed an intensive drain on the Copper River runs of king and red salmon. In five years the number of canneries grew from 1 to 9, one of which, as already indicated, was located several miles up the river and made its entire catch in Miles Lake and Abercrombie Canyon. Set nets were used in the lake and dip nets in the canyon. In the delta district, where set-net and drift-net fishing had been followed for years, staked nets were added and used extensively over the mud flats. Traps were also tried on the flats, but the district proved to be unsuited for that form of appliance.

The confusion of Copper River and Prince William Sound figures in the early catches has been fully discussed above in connection with the data for the eastern part of the sound. Table 10 gives the combined catches of the two districts for the years 1889 to 1903, inclusive. The catches of reds and kings are undoubtedly chiefly (and for several years exclusively) composed of Copper River fish. Probably most of the pinks were secured in the sound. The records of the catches of cohos are of doubtful value on account of the possibility of errors as to species and uncertainty as to the source of the catch. Although it has seemed best to keep the early figures separate from those collected by the bureau since 1904, it may be assumed with little chance for serious error that the data for kings and reds may be combined to give a complete statistical account of the catches of these two species. The salmon catches on the Copper River from 1904 to 1927 are given in Table 11 and may be taken as reliable and accurate within the limits reasonably applicable to such data.

TABLE 10.—*Salmon caught and fishing appliances used in the Prince William Sound and Copper River districts, 1889 to 1903*

Year	Cohos [1]	Pinks	Kings	Reds	Beach seines	Gill nets
					Number	*Number*
1889				242, 790		
1890			5, 491	411, 190		
1891			6, 185	710, 740		
1893	72, 000		8, 674	792, 690		
1894	17, 000		8, 494	710, 000		
1895	142, 937		10, 248	507, 630		
1896	31, 862	308, 180	1, 407	714, 595		
1897	25, 605	302, 290	2, 044	371, 487	5	10
1898		375, 246	1, 850	417, 171	12	10
1899		212, 907	4, 682	527, 122	12	10
1900	88, 175	50, 565	3, 462	748, 310	2	10
1901		313, 806	6, 558	781, 438	2	10
1902		375, 408	2, 500	800, 044		10
1903		398, 926	4, 600	814, 345	2	10

[1] Reported as cohos but probably mainly pinks.

The number of localities in the Copper River district has been reduced to four by combining all catches reported from Eyak Lake and Mountain Slough with Eyak River fish. Glacier and Martin River catches are given exactly as reported by the fishery operators. The Copper River catch includes all salmon caught in Abercrombie Canyon and Miles Lake, all salmon from the many sloughs of the delta, besides small lots reported from Big Softuk Bar, Boswell Bay, Copper River Flats, Cottonwood Point, Egg Island, Italian Flats, Kokinhenik Bar, Little River, Point Whitshed, San Island, Snag Point, and Softuk Bar. In the period from 1904 to 1914, when the district was occupied by a single cannery and fishing was confined largely to the sloughs, there was less chance of error in the allocation of catches than in subsequent years when fishing became more intensive and the mud flats were covered with staked nets. The general intermingling of all runs of salmon in the tidal sections of the district where much of the catch was made in later years rendered more definite allocation a hopeless undertaking if not an impossibility. Perhaps the most logical disposition would be to credit all salmon taken between Point Whitshed and Point Martin to Copper River, disregarding entirely Eyak, Glacier, and Martin Rivers. It is possible that most of the salmon reported as coming from these streams were Copper River fish, for it is recognized that the spawning grounds of Eyak Lake are extremely limited and can accommodate at most only a few thousand salmon, that Glacier River is equally deficient, and that Martin River is in reality a tributary of the Copper. In spite of these recognized deficiencies in the data it has seemed best to retain such details of the catch as have been given although analysis of the catches in the smaller localities can not be considered well founded.

TABLE 11.—*Salmon caught and fishing appliances used in the Copper River district, 1904 to 1927*

Year	Cohos	Chums	Pinks	Kings	Reds	Gill nets		Dip nets	Traps
						Number	Fathoms		
Copper River:								*Number*	*Number*
1904				4,812	459,360				
1905				20,000	272,000				
1906				2,020	194,519				
1907				789	156,203				
1908					350,094				
1909				3,067	218,140				
1910	5,142			974	142,456				
1911	11,844			1,317	321,442				
1912	12,846			6,025	223,420				
1913				2,233	278,967				
1914	14,949			3,029	305,379				
1915	12,098		15,162	7,313	716,352				
1916	115,430	67	31,578	14,211	732,904				
1917	99,526			13,247	772,113				
1918	62,368	686	5,361	19,226	1,260,032				
1919	40,650			13,187	1,238,168				
1920	73,924			22,994	853,675				
1921	377			11,466	567,149				
1922				9,924	483,140				
1923			461	10,301	54,031				
1924	41,884	23	186	14,093	733,076				
1925	141,549		9	19,081	149,991				
1926	177,527		85	21,329	207,455				
1927	285,523		4	40,785	282,030				
Eyak River:									
1904					26,000				
1905					40,000				
1906				32	22,385				
1907				80	48,262				
1908					55,158				
1909					64,357				
1910	6,487				34,285				
1911	14,849			5	39,767				
1912	20,744			17	180,743				
1913					78,869				
1914	15,519				193,254				
1915			910	2	56,733				
1916	2,737			44	23,739				
1917	17,196		8,845	549	102,429				
1918	12,011			92	143,774				
1919	12,818			79	79,078				
1920				2	906				
1921					1,397				
1922				14	14,050				
1923				12	67,175				
1924	5			21	33,485				
1925	10,592	4	11	47	10,630				
1926	241			3	3,678				
1927	75,285			271	39,525				
Glacier River:									
1908					6,050				
1909					1,741				
1910	6,520				22,592				
1911	6,967			21	18,277				
1912	2,648			138	35,690				
1913				74	38,425				
1914	11,724			14	66,892				
1915			4	18	37,125				
1917	6,856			99	28,078				
1918				160	38,087				
1920				1	43				
1921					1,745				
1922				135	6,724				
1923			1	20	4,689				
1924				1,748	24,274				
1925	972			600					
1926	13			6	208				
1927	49,542			989	19,736				
Martin River:									
1904				202	16,270				
1905					8,000				
1906				113	48,474				
1907					59,092				
1908					55,112				
1909					32,450				
1910					22,660				
1911				15	28,073				
1912				1	16,537				
1913					8,653				
1914					5,434				
1915				1	8,518				
1916				4	12,888				
1917	2,495			35	17,198				
1918				149	50,463				
1919					11,397				
1922				2	1,861				

TABLE 11.—*Salmon caught and fishing appliances used in the Copper River district, 1904 to 1927*—Continued

Year	Cohos	Chums	Pinks	Kings	Reds	Gill nets		Dip nets	Traps
						Number	Fathoms		
Martin River—Continued.								*Number*	*Number*
1923				6	808				
1925	263								
Total:									
1904				5,014	501,630	38			
1905				20,000	320,000	26			
1906				2,165	265,378	20			
1907				869	263,557	20	1,333		
1908					466,414	26	1,733		
1909				3,067	316,688	26	1,517		
1910	18,149			974	221,993	27	1,560		
1911	33,660			1,358	407,559	33	1,810		
1912	36,238			6,181	456,390	56	4,000	2	
1913				2,307	404,914	31	1,925	4	
1914	42,192			3,043	570,959	34	3,200		
1915	12,098		16,076	7,334	818,728	72	5,433		
1916	118,267	67	31,578	14,259	769,531	326	27,485	50	3
1917	126,073		8,845	13,930	919,818	501	36,914	70	4
1918	74,379	686	5,361	19,627	1,492,356	519	37,545	36	2
1919	53,468			13,266	1,328,643	691	54,625	35	2
1920	73,924			22,997	854,624	748	57,401	183	3
1921	377			11,466	570,291	471	35,700	165	1
1922				10,075	505,775	638	47,160		1
1923			462	10,339	625,875	663	47,025		
1924	41,889	23	186	15,862	790,835	488	40,500		
1925	153,376	4	20	19,728	160,721	497	31,124		
1926	177,781		85	21,338	211,341	555	33,450		
1927	410,350			42,045	341,291	495	30,950		

NOTE.—No catch was reported in the years not shown in the table.

Except in 1892 when all canneries in this district were idle there was no interruption of fishing from 1889 to 1927. For many years operations were unrestricted as the law of June 26, 1906, specifically exempted the waters of the delta of the Copper River and tributaries from its protective provisions. In 1912, Eyak Lake and its tributaries were closed to all commercial fishing for salmon, and a seasonal limitation was placed on fishing in Eyak River. Regulations affecting fishing in Copper River and throughout the delta district were made operative in 1918. They prohibited all fishing before June 1 of each year, established a weekly closed season, prescribed fishing appliances and distance interval between nets, prohibited all fishing in the river from the delta to Miles Lake and closed certain sections of Abercrombie Canyon and the entire river above the canyon to all operators except local residents taking salmon for domestic use. In 1919, the general closed season was extended 10 days, the length of nets in the delta section was reduced but in Miles Lake it was increased, the west and north shores of Miles Lake and the east side of the river above the lake and through the canyon were closed to all fishing. On September 1, 1921, all fishing in Copper River and its tributaries and within 500 yards of each mouth of the river was prohibited, bringing to a close the operations at Abercrombie Canyon and Miles Lake. After the passage of the new fishery law in June, 1924, the open season was advanced 20 days, making it possible for fishing to begin at midnight May 25 of each year; the 36-hour closed period provided by law was extended to 60 hours, stake nets were limited to 600 feet in length, and traps were prohibited. In 1925 all previous regulations were supplanted by a new order which became effective on January 1, prohibiting the capture of salmon in the Copper River district from July 11 to August 19; the use of nets of mesh less than 8½ inches before May 20; the use of stake nets, set or anchored gill nets, and traps at all times; all fishing within 500 yards of the grass banks of the delta; the use of gill nets attached to anchored boats or other equipment; authorizing the use of stake nets from the grass banks after August 10, and removing

all restrictions on the amount of fishing apparatus used by each boat after August 10. The same regulations were continued in 1926 except that the closed season was shortened 9½ days, minor prohibitions in the use of 8½-inch mesh nets within 2 miles of the mouths of streams were added, and the weekly closed period was extended to 60 hours through July 10. In 1927 the weekly closed period was changed to 48 hours from May 20 to July 10, boats were limited to the use of 250 fathoms of net except that from May 20 to May 31 an additional 100 fathoms of 8½-inch mesh gill net could be used.

During this period of adjustment the catch of salmon fluctuated considerably from year to year, possibly due to the continually changing regulations and irrespective of the size of the runs. When the drastic regulations of 1925 became effective, the catch of red salmon dropped to the lowest level it had reached in the entire history of the Copper River fishery, only 160,721 being taken, and the catch in 1926, under a slight relaxation of the regulations, was only 211,311 reds, next to the lowest ever made. The catch had not fallen below half a million during the entire period from 1914 to 1924, inclusive.

In 1918 the catch was nearly a million and a half reds, 20,000 kings, 75,000 cohos, and a few hundred pinks and chums. This catch was produced by an aggregate of 37,500 fathoms of gill nets, 36 dip nets, and 2 traps. In 1920 the catches of all other species than reds was about the same as in 1918; but the catch of reds was much smaller, only a little over 850,000 in spite of the use of considerably more gear—57,400 fathoms of gill nets, 183 dip nets, and 3 traps. The regulations for these two years favored the season of 1918 as the longer closed season in 1920 and the closure of certain areas in the up-river fishing grounds naturally reduced the catch in that year, but it would seem that an increase of 52 per cent in the fishing effort would more than counterbalance the additional restrictions then applied although it is possible that the catch per unit of gear may have been materially decreased by the competition between units. (See Pt. I, p. 77.) A comparison of the catches in 1919 and 1920 under identical regulations and with practically the same amount of gear shows a difference of 36 per cent in favor of 1919. It is probable, therefore, that this smaller catch in 1920 was due to biological causes and reflected a smaller run of salmon in 1920.

Figure 10 shows in graphic form the catch of king and red salmon in the Copper River district for 39 years.

In respect to red salmon, the graph shows that the first noteworthy peak in production was reached in 1902 and 1903; this seems to be due entirely to the number of canneries operating rather than to the quantity of fish available, as with each increase or decrease in the number of operators the catch rose or fell correspondingly. After 1903 the catch immediately dropped to a much lower level for the simple reason that but one company was then operating. For the same reason it remained low during the next 10 years, the catch limit being fixed by the packing capacity of the cannery and not by the size of the run. In later years, with the introduction of more canneries, the size of the catch undoubtedly bore a direct relation to the size of the runs; and this continued until regulations changed the situation, affected operations, and reduced catches so as to leave no basis for determination of size of runs by measurement of catch in a single season. The number of kings and cohos taken in 1927 was nearly double that of any other year; chums and pinks are practically unknown in the district.

No definite evidence of serious depletion, therefore, can be seen in this district in spite of the greatly reduced catches of red salmon since 1924, since the catches of recent years have been made under totally different conditions. If the small catches

of 1925 to 1927 had been made under the same restrictions and regulations as were imposed in 1918 and 1919, with the gradually declining catches of the intervening years as further evidence, it might reasonably be held that the fishery had been rapidly depleted. However, this was not the case, and it appears more probable that the chief factors responsible for the reduced catch have been economic rather than biological. There have been, undoubtedly, some very poor runs in recent years, since not only have the commercial catches been poor but there has been a marked scarcity of salmon, as shown by the failure of fishing operations for local use in the

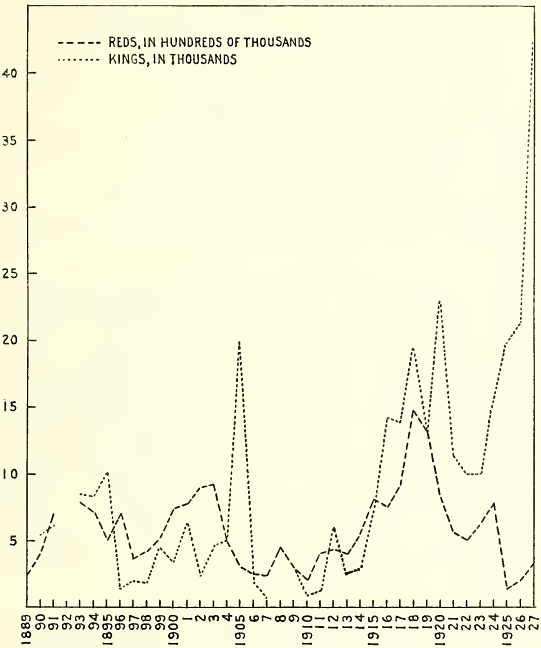

FIGURE 10.—Catch of king and red salmon in the Copper River district

upper river; but, so far as the present evidence goes, there is little indication of serious depletion.[7]

BERING RIVER

The Bering River district embraces the coastal waters of central Alaska from Point Martin on the west to Cape Suckling on the east, including Bering River, a tributary of Controller Bay which bay practically covers the coast from Point Martin to Okalee Spit and forms the principal fishing ground of the district. Bering River

[7] A more detailed analysis of the statistics of the red-salmon fishery of the Copper River is being made by Seton H. Thompson and will be presented in a separate report. Although this analysis is incomplete as yet it may provide more evidence of depletion than has been apparent in the data presented in this report.

is the outlet of a few small lakes and also receives much of the discharge from the western part of Bering Glacier. About midway between the source and the mouth of the river is Bering Lake, a shallow body of water having an area of about 20 square miles. The lake is subject to tidal influence and is not regarded as an important spawning ground of red salmon, though it is probably used rather extensively by cohos. This district is shown in Figure 9.

Fishing began in this district in 1889 when two canneries were built on Wingham Island. Though both plants had abandoned this location by 1891, one going to Thin Point and the other to Kokinhenik Island at the mouth of Copper River, it is not likely that fishing at Bering River was discontinued. No records are available, however, to show that salmon were taken here before 1896, yet it seems very probable that the locality was fished regularly after canneries were once established, even in the years from 1907 to 1911, inclusive, when, according to records now obtainable, no catches were made. If the companies at Odiak and Orca found it profitable to fish this locality in 1904 and 1906 and since 1911, there is no reason to suppose that salmon were not obtainable there in commercial quantities in the intervening years. Such catches were undoubtedly reported as Copper River fish.

A cannery was built on Bering River in 1916, primarily to pack Bering and Copper River salmon. The district was also visited by fishermen from canneries more recently established at Cordova and was fished somewhat regularly by them for several years.

Prior to 1918, no restrictions on fishing in Bering River were imposed other than those provided in the general law. In that year a regulation was made effective which closed Bering Lake and the river above a point a few hundred feet northwest of the mouth of Gandil River, an eastern tributary of the Bering. This prohibition was continued through 1923. Under the law of 1924, restrictions were increased by an order extending the weekly closed period to 60 hours and prohibiting the use of staked nets more than 600 feet in length. In 1925, fishing was prohibited before May 26, and also from July 11 to August 19. From June 1 to July 10, the weekly closed period was extended to 48 hours; nets with mesh less than 8½ inches stretched measure were prohibited before June 1; and only drift gill nets not more than 200 fathoms in length were permitted at any time. Modifications were made in 1926 whereby the prohibition against fishing prior to May 26 was removed, the closed season was extended from July 10 to August 10, ending nine days earlier than in 1925. After August 10, each fishing boat was allowed to carry 350 fathoms of net. All fishing in the Bering River district was prohibited in 1927.

Table 12 gives a detailed statement of the catch of all species of salmon reported from the Bering River district from 1904 to 1926, consisting chiefly of red and coho salmon, though small numbers of kings were caught in several years. Occasionally pinks were taken in small quantities, but chums are practically never taken. It is evident from the number of nets operated from 1896 to 1915 that the district was not fished intensively. But the season of 1916 marked the beginning of an increased fishing effort, which reached a peak in 1918 but declined approximately 50 per cent in the following season. Thereafter it fluctuated considerably but rose again in 1922 almost to the level of 1918. The fishing effort in 1920 and 1921 resulted in exactly the same average catch per fathom of gill net in both years, which was 28.7 red salmon per unit. In 1917, 1918, and 1922, the years of maximum effort, the average catch per unit was only 13.9 red salmon. The largest catch of reds was made in 1923 when little more than half the gear used in 1918 produced approximately 90

per cent as many fish. It appears probable that these fluctuations in catch per unit of gear are due at least in part to the disturbing effect of competition between the units of gear and do not at all reflect corresponding fluctuations in actual abundance of fish.

TABLE 12.—*Salmon caught and fishing appliances used in the Bering River district, 1896 to 1927*

Year	Cohos	Chums	Pinks	Kings	Reds	Gill nets		Traps
						Number	*Fathoms*	*Number*
1896					23, 980			
1897					39, 269			
1898					39, 383			
1899					27, 072			
1900					106, 167			
1904				400	123, 400	20		
1906				111	54, 074	5		
1912	8, 000				41, 023	10	1, 000	
1913					38, 519	15	1, 250	
1914					10, 202	1	50	
1915				4	105, 614	15	1, 050	
1916	51, 938		14, 492	7	141, 278	83	7, 740	
1917	78, 412			321	163, 357	105	11, 325	
1918	80, 218	3	772	139	173, 021	141	13, 400	
1919	76, 729			72	139, 792	65	6, 650	
1920	63, 865			120	162, 582	50	5, 650	
1921				3	120, 667	60	4, 200	
1922				72	131, 179	96	13, 210	1
1923	24, 723		298	86	192, 361	82	7, 250	
1924	80, 030			111	87, 114	31	4, 050	
1925	57, 018		206	77	52, 632	53	5, 150	
1926	52, 668		135	76	37, 424	66	5, 800	

NOTE.—The catch of red salmon from 1896 to 1900 was taken from Moser's report for 1900 and 1901 and represents the number of salmon caught by the Alaska Packers Association only. Another company was operating in the Bering River district but we have been unable to find any records of the catches made by it.

The table includes 14,032 cohos reported from Okalee River in 1919 and 12 kings and 15,233 reds from Controller Bay in 1922. No catches were reported in the years not shown in the table.

Table 13 shows graphically the catch of reds at Bering River from 1912 to 1926. Data for the earlier years were not included as the record was not continuous. Beginning with the intensive exploitation of this fishery in 1915, the catch increased steadily until 1918. This gradual rise was followed by mild fluctuations, the catch dropping in the odd years and ascending in the even years until 1923 when it reached its highest level. The smaller catch in 1921 can be traced to economic conditions which resulted in the temporary closing of the Bering River cannery so that the lower level of production in that year does not reflect the true condition of the fishery. In the next three years, it declined progressively to the lowest level reached in 12 years, due undoubtedly to the stringent regulations which were then enforced. There is no clear evidence of depletion in these data.

TABLE 13.—*Graphic table showing the catch of red salmon in the Bering River district, 1912–1926*

[Each letter represents the following number of fish: Reds, 10,000]

Year	Reds
1912	mmmmM
1913	mmmm
1914	mm
1915	mmmmMmmmmMm
1916	mmmmMmmmmMmmmmM
1917	mmmmMmmmmMmmmmMmm
1918	mmmmMmmmmMmmmmMmmm
1919	mmmmMmmmmMmmmm
1920	mmmmMmmmmMmmmmMmm
1921	mmmmMmmmmMmmm
1922	mmmmMmmmmMmmmm
1923	mmmmMmmmmMmmmmMmmmmM
1924	mmmmMmmmm
1925	mmmmMm
1926	mmmm

SENSORY STIMULATION OF THE OYSTER, OSTREA VIRGINICA, BY CHEMICALS

By A. E. Hopkins, Ph. D., *Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

Although the adult oyster is immobile it is, like a great many other organisms, highly sensitive to environmental changes, both chemical and physical. The obvious reaction of the oyster to stimuli is a quick closing of the valves, brought about by contraction of the adductor muscle. This may be observed following mechanical or chemical irritation or sudden decrease in the intensity of the light; the so-called shadow reaction. It is not the purpose of this paper to give a complete account of the oyster's sensitivity to all environmental factors, but it is of interest that the only reaction, ordinarily to be observed, to stimuli of various kinds is the shell closure. Because of its immobility and its consequently limited number of possible reactions the oyster is a favorable object for experiments on sensitivity.

The sensitivity of invertebrates and lower vertebrates to a wide variety of chemical substances has been studied by numerous investigators. It is unnecessary to make a complete survey of such works here, but certain of them should be mentioned to indicate the scope of the chemical senses. Amphioxus (Parker, 1908) has been found to respond to solutions of salts, acids, alkalies, alkaloids, alcohol, ether, chloroform, turpentine, and several essential oils, but not to cane sugar of a concentration as high as 2 molar. Kribs (1910) gave the threshold concentrations of a number of substances in the stimulation of the Oligochaet, Aelosoma, as follows: Mineral acids, N/3,000; organic acids, N/2,000; hydrates, N/1,500; carbonates, N/1,200; chlorides, M/80; bromides, M/50; ferric sulphate, M/10,000; copper sulphate, M/80,000; zinc sulphate, M/80,000. He stated that increase in temperature or exposure to bright light lowered the threshold.

Crozier (1915) studied by means of reaction times and threshold concentrations the responses of *Holothuria surinamensis* to salts, acids, carbohydrates, and alkaloids. Similar observations have been made by Olmstead (1917) on *Synaptula;* Hecht (1918) on *Ascidia;* Crozier and Arey (1919) on *Chromodoris;* Arey and Crozier (1919) on *Chiton;* Agersborg (1922) on *Nudibranchs;* Copeland (1923) on *Palaemonetes;* Copeland and Wieman (1924) on *Nereis;* and various others. A recent review of the significant findings of these workers is that of Parker and Crozier (1929).

MATERIAL AND METHODS

The experiments described in the following pages were made at the biological laboratory of the United States Bureau of Fisheries at Beaufort, N. C. Large local oysters (*Ostrea virginica*) were employed.

By sawing through the posterior portion of the right valve of a specimen, it was possible to remove the severed piece of shell without injury to the underlying tissues. The mantle, with its border of 2 rows of tentacles, 2 to 5 millimeters long, was in this manner exposed. The method by which a chemical solution was brought into sudden contact with the tentacles has already been described (Hopkins, 1932). By means of an arrangement of constant levels a stream of water flowed through a small tube across a few tentacles. By making a quick turn of a 3-way stopcock the stream of water was suddenly replaced by the chemical solution to be tested. The total time from turning of the stopcock until the retraction of the tentacles was measured with a stopwatch. The time required for the solution to go from the stopcock to the tentacles was measured by use of a colored solution. This value was then subtracted from the total time measured, giving the actual latent period, or the time required for the reaction to take place after the solution reaches the tentacles.

The test solutions were made up in sea water so as to eliminate any possible effect of distilled water. When stimulated by a chemical solution the tentacles of the oyster retract sharply, so that the latent period may readily be measured. The reaction to distilled water, or to sea water diluted with equal parts of distilled water, or to sea water concentrated to half its original volume, is quite different. In these cases the tentacles retract very slowly, and it is almost impossible to determine the time of beginning of the movement. This is in marked contrast to the quick jerk of the tentacles when stimulated by an irritating solution and is clear evidence that the latent periods determined in the experiments were not due to differences in osmotic pressure.

EXPERIMENTAL OBSERVATIONS

No attempt has been made to list all substances which may stimulate the oyster. The purpose of the experiments was to find out how the reaction time varies with concentration in enough types of compounds to indicate whether the same principles obtain in all cases. One substance was tested which in man is an adequate stimulus for the sense of smell, namely, cumarin. This has an odor similar to that of vanilla and at fairly high dilutions, at least, seems to have no taste as distinct from odor.

As representatives of substances commonly identified with the sense of taste the following compounds were employed: Several inorganic salts; quinine sulphate; cane sugar; hydrochloric acid (though these results were not totally satisfactory because of the difficulties concerned with acid in sea water); and alkalies, namely,

sodium hydroxide and potassium hydroxide. The alkalies are often thought to be stimuli for the common chemical sense rather than for taste.

The results are presented graphically and each point represents the average value of from 10 to 20 latent period determinations. Five minutes were allowed to elapse between succeeding tests to prevent possible fatigue of the sensory endings. A single complete series, involving tests for enough concentrations to produce a relatively complete curve, was made within two or three successive days and under conditions as nearly constant as possible. The temperature of the water during a series varied over approximately 3° C. and was in general close to 20° C. It is not known at present how great is the error due to temperature fluctuations, but the probable error in any group of tests with a single concentration did not exceed ±0.05 second, except in certain cases which will be mentioned later.

CUMARIN

In general the latent period values were not more than about five seconds, for above this the reaction was so weak as to be indistinguishable from the frequent slight movements of the tentacles. However, in the case of cumarin the reaction was sharp and clear up to about 14 seconds, although the probable error increased to about ±0.3 second. In Figure 1 the results of a series with one specimen are presented. It is unnecessary to give more for, aside from a slight individual variation, the other series agree perfectly with this one. Concentrations from 0.0004 to 0.011 per cent were tested, and the points as shown in the figure fall with reasonable accuracy into a hyperbolic curve. Crozier (1918, 1918a) obtained similar curves in studies on the stimulation of the earthworm by acids and alkalies. The relationship between concentration (C) and latent period (T) is what would be expected for a simple monomolecular chemical reaction; namely, $C \times T = K$.

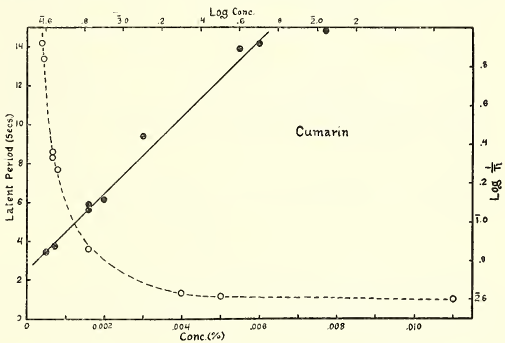

FIGURE 1.—Graph showing average latent period values (open circles) as ordinates for different concentrations (abcissae) of cumarin, and same data (solid points) plotted as log of reciprocal of latent period and logarithmic concentration

On the same graph the data are given logarithmically, as logarithmic concentration (abcissæ) and logarithmic 1/latent period (ordinates). The points fall close to a straight line with the exception of that referring to the highest concentration. Whether the latent period at high concentrations actually reaches a limit and changes the form of the logarithmic curve or whether the error is too high to permit accurate determination is not quite clear. The latter possibility, however, is very likely, for at high concentrations the latent period is extremely short and the reaction involves not only the tentacles but also the adjacent portion of the mantle.

POTASSIUM CHLORIDE

Latent period studies were made with a number of inorganic salts, but at this place data need be given for only KCl, NaCl, and $MgCl_2$.

A typical record is that shown in Figure 2 for potassium chloride. The latent period values all fell within 2.5 seconds, but the curve is nevertheless very similar to that just described. It was possible to measure the reaction time for concentrations as low as 0.01 M., but solutions of 0.2 M. or higher caused such violent contractions of the whole mantle that the difficulties of experimentation were great.

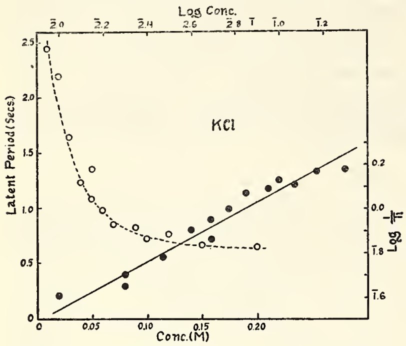

FIGURE 2.—Average latent period values (open circles) for solutions of potassium chloride of different concentrations; and the same data expressed logarithmically

The logarithmic curve (fig. 2) is similar to that shown in Figure 1, except that the angle made with the horizontal axis is less. Typical of nearly all of the records for salts is an angle of less than 45° for the logarithmic curve. It is assumed that this is due to some factor, such as diffusion, which causes the latent periods to be longer than expected. That is, the relationship, $C \times T = K$, must be modified to $C \times (T - X) = K$. The significance of the factor, X, will be discussed later.

SODIUM CHLORIDE

In Figures 3 and 4 the results of two series of tests with solutions of NaCl are given. The series were made with different specimens at different times, and the latent period values of series 1 are consistently higher than those of series 2. This difference probably was not due to temperature for that was approximately the same in both cases. It may have been due to difference in light intensity, for according to Kribs (1910) bright light sensitizes the chemical receptors of Aelosoma. It was possible to measure the reaction time at concentrations only as low as 0.1 M., which is very high as compared to the threshold for KCl. It is well known, however, that the potassium ion is very highly stimulating to many organisms (Hopkins, 1932).

In Figure 4 the two curves are presented in logarithmic form. The curves are drawn through the points as parallel lines, though this need not necessarily be the case. The angle of the curves is less than 45°, as in the case of KCl, and all other salts.

MAGNESIUM CHLORIDE

It has been a source of confusion in this work that in certain experiments the latent period seemed to change almost suddenly from short to long. For example, during a series of tests with one concentration of a salt, the latent period for a number of tests would be consistently about one second. Then, for no obvious reason, the reaction would follow a latent period of perhaps 1.8 seconds. At other times it might shift from long to short; or two separate and distinct reactions at the two levels might be observed. When the tests were first made with $MgCl_2$ this was found to occur

and it was thought to be peculiar to this salt. However, it has been found to be possible with other salts as well. In Figures 5 and 6 the results of one series of tests with

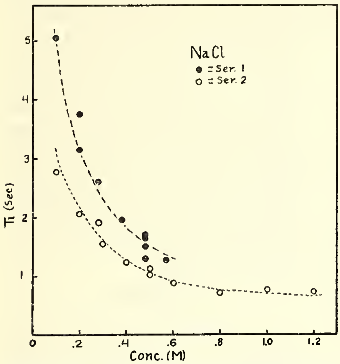

FIGURE 3.—Average latent period values (ordinates) of the reaction of the oyster to different concentrations (abcissae) of sodium chloride. Two series of experiments made under different conditions are given. (See fig. 4)

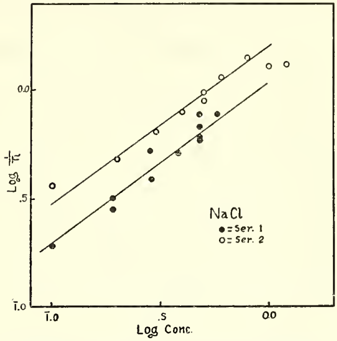

FIGURE 4.—Data given in Figure 3 plotted as logarithmic reciprocal of latent period and logarithmic concentration

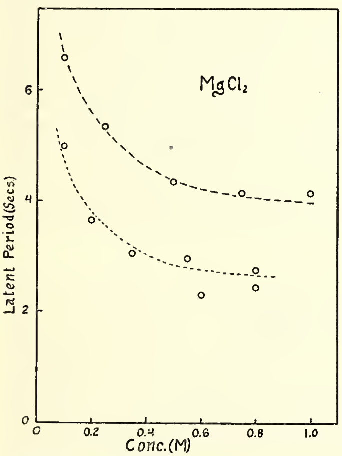

FIGURE 5.—Curve showing two different latent period levels in the response of a single specimen to magnesium chloride. The points represent averages. (See fig. 6)

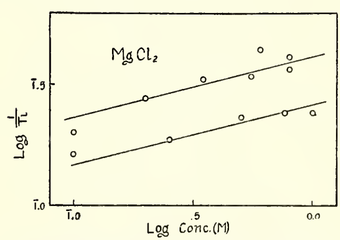

FIGURE 6.—Logarithmic presentation of data given in Figure 5 showing relation between logarithmic concentration and logarithmic reciprocal of latent period

$MgCl_2$ are given. The points fall clearly into two approximately parallel curves about one second apart.

The two curves are mathematically comparable. Further experiments are in progress for the purpose of finding the significance of this behavior.

QUININE SULPHATE

The reactions of the tentacles to quinine are in every way comparable to those to the salts just described. The curve (fig. 7) is a typical hyperbola and the points, logarithmically expressed, fall around a straight line which has an angle, however, of less than 45°. A distinct and measurable tentacular reaction was observed as a response to concentrations as low as 0.0004 per cent. According to Hecht (1918) the taste threshold in man for quinine sulphate is 0.00004 M. Since the oyster is sensitive to 0.0004 per cent, or about 0.0000046 M., the latter is about eight times as sensitive to this substance as man.

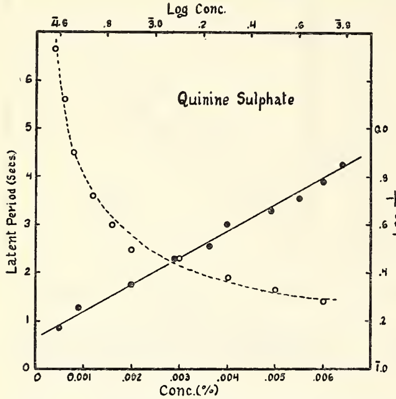

FIGURE 7.—Average latent period values of the response of the oyster to quinine. On the same graph (solid points) the data are expressed logarithmically

ALKALIES

The difficulty of working with alkalies in sea water is great unless artificial, carbonate-free sea water is employed. In experiments of the present kind it is necessary for the specimens to be immersed in a considerable quantity of running water in order to insure against building up of a significant concentration of the test chemical in the medium. For this reason it is impractical to use artificial sea water entirely. Experiments might be made in which the specimens are immersed in natural sea water and only the solution of alkali in carbonate-free water. This procedure, however, would probably not be satisfactory, for in order to bring about stimulation it is necessary for the test solution to come into contact with the tentacles which are already immersed in sea water, and reaction between the molecules of alkali and carbonate would take place close to the sensory surfaces. In such a case precipitation compounds would be formed.

In these experiments such possible sources of error were recognized, but a few series of tests were made without attempting to eliminate the difficulties. Nevertheless, the results appear to be of considerable significance. Stock molar solutions of KOH and NaOH were made in sea water. The precipitate of magnesium and calcium carbonate was allowed to settle and the solution decanted and filtered. Immediately preceding a series of tests the desired concentration was made from the stock solution and sea water. Again a precipitate was formed and removed by decanting and filtration. When the test solutions came into contact with the tentacles there was probably further precipitation. However, in all except possibly the most dilute solutions the hydroxyl-ion concentration was sufficient to remove all of the carbonates from the test solutions. The concentrations of alkali as stated in terms of mols of alkali originally dissolved, while not strictly correct, are relatively correct with relation to one another.

This will appear more clearly when Figures 8 and 9 are examined. One series of tests each for NaOH and KOH are given in the graphs. Three such series were

made, but the others are entirely comparable and need not be given. In Figure 8 the curves representing the latent period values for each concentration are entirely different for the two alkalies. While the latent periods for KOH fell into a curve typically like those described in the preceding pages, the results obtained with NaOH fall distinctly into two such curves (A and B, fig. 8) which cross one another at a concentration of about 0.07 M.

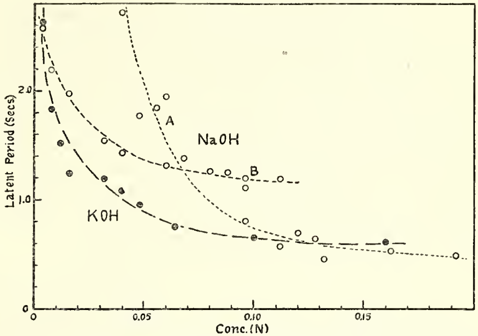

FIGURE 8.—Average latent period values for different concentrations of KOH (solid points) and NaOH (open circles). (See fig. 9)

In measuring the latent period of the tentacular reaction the time up to the first visible sharp reaction is used. It was observed in the early experiments with NaOH (fig. 8) that the latent period for concentrations of 0.1 M. or above were very short, and at the next lower concentrations much longer than expected. There appeared to be a sudden break in the curve. When tests with various concentrations were repeated it was found that one series would give a long reaction time and another series with the same solution would give a short latent period. The points appeared to fall along the lines as shown in the figure. It is probable that the reactions in both latent period groups occurred in all cases, but that at some times those of one group would be sharp enough to be detected while at other times the clear reactions would fall into the second group. For some time during the tests it was thought that the error of the method was simply very large, but the latent period values persisted in falling along the lines shown.

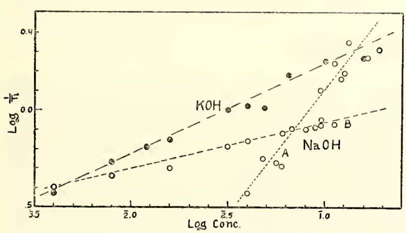

FIGURE 9.—Latent period data given in Figure 8 expressed logarithmically. (See text)

The records obtained with KOH, on the other hand, were of a decidedly different sort (fig. 8). So far as could be determined the latent period curve was single. The points fall into a curve similar to those of the salts. By plotting the results logarithmically (fig. 9), the dual nature of the results with NaOH is made even clearer. While the points representing the reaction to KOH may be considered to fall into a single straight line, two such lines are required to satisfy the values obtained with NaOH. The difference is probably of some significance for all of the tests were made upon a single specimen within the period of a few days.

In the description of the experiments with salts it was pointed out that the logarithmic curves made an angle of something less than 45° with the horizontal. In Figure 9 it appears that the angle made by the KOH curve is only about 20°,

while that of one NaOH curve (B) is even less, and of the other (A) is approximately 45°. If it be assumed, as seems reasonable, that the small angle of the curves is due to the time required for the stimulating substance to penetrate a layer of mucus on the tentacles, a possible explanation of these curves may be obtained. It has been pointed out that the potassium salts are much more efficient than sodium salts in the process of stimulation.

While the threshold for KCl is 0.01 M., that for NaCl is 0.10 M., or 10 times as high. It may be that the two ions in solutions of KCl or KOH stimulate separately, and that the observed latent period is that due to the ion which initiates the reaction first. Then, if it be assumed that the curve for KOH (figs. 8 and 9) is a record of the stimulation by potassium ions, it is probable that the NaOH curve *B* represents the response to sodium ions, and curve *A*, OH ions. If this is the case, it would appear that the OH ions penetrate the layer of mucus much more rapidly than the ions of Na or K. Consequently the concentration of OH ions × the latent period is a constant, for the logarithmic curve has the angle of 45°. However, the time required for penetration of the mucus by Na and K ions must be subtracted from the latent period in order for this relationship to obtain.

CANE SUGAR

Parker (1908) stated that it appears that cane sugar does not stimulate the sensory receptors of Amphioxus. Similar results were obtained with the oyster. Only when a very high concentration of sugar was employed did the tentacles retract, and then the reaction was similar to that due to diluted or concentrated sea water. The effect obviously was due to osmosis by extraction of water. Crozier and Arey (1919) obtained similar results with *Chromodoris*, but found (Arey and Crozier (1919)) *Chiton* to be sensitive to 0.5 M. sucrose and lactose.

Negative evidence such as this is, however, of doubtful significance. The reaction of the oyster to the solutions employed is negative. The retraction of the tentacles or mantle appears to be of a protective nature and results in the withdrawal of these organs from the source of irritation. It is not impossible that substances such as sugar may stimulate the receptors positively and that the reaction as to irritation does not take place.

DISCUSSION

A source of constant difficulty in the experiments described in the foregoing pages is the occasional sudden change in the latent period values from a low to a high level, or vice versa. One example was given (figs. 5 and 6) in which two distinct curves were obtained. It was thought possible that frequent stimulation might result in fatigue of the receptors or in sensitization like that observed by Irwin (1918) to follow successive stimulation with a strong potassium salt. It seemed also possible that changes in light intensity or temperature might cause variations in the threshold (Kribs, 1910). However, no evidence has been obtained that any of these suggestions is the case. There appear to be definite levels at which the response to any concentration of a salt takes place. It has frequently happened that two separate and distinct responses may be observed, and measured, following stimulation. At other times either the lower or the higher reaction time may be measured. It is as if both such reactions always occur and that in some cases one is distinct and the other too weak to be observed.

The question arises as to whether the reactions are due to stimulation of different sensory endings the thresholds of which are different. Or possibly different receptors are stimulated separately; one, for example, by the anions, another by cations, and still another by undissociated molecules. This is a problem which may be solved, and further experiments are under way for this purpose.

What appears possible is that there is a measurable refractory period of the tentacular muscle fibers and that following initial stimulation contractions follow at regular intervals. Stimulation results first in retraction of the tentacles involved and then, after a considerably longer latent period, the adductor muscle contracts, closing the valves. In Figures 10 and 11 the results of a series of tests are given to show the relationship existing between the initial response of the tentacles and the following reaction of the adductor muscle. It is not practicable to employ the response of the

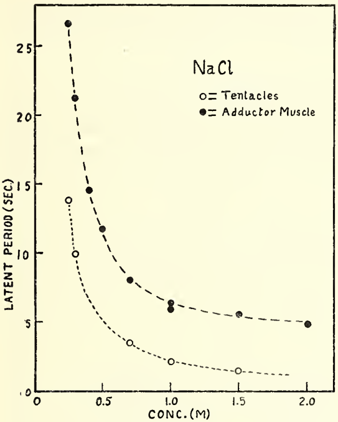

FIGURE 10.—Average latent period values for the tentacular (open circles) and adductor muscle (solid points) reaction to a series of concentrations of sodium chloride. (See also fig. 11)

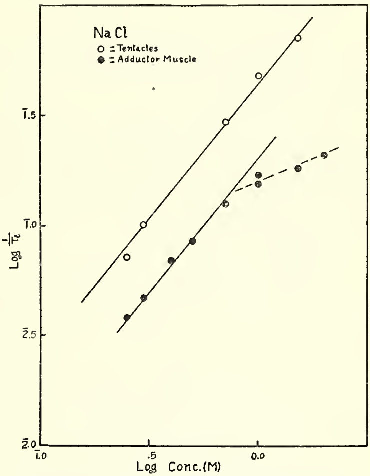

FIGURE 11.—Logarithmic expression of data given in Figure 10 for responses of tentacles and adductor muscle to sodium chloride

adductor muscle in this work, for after the oyster has been stimulated a few times the shells close and remain so for a considerable period.

Certain experiments with mixtures of substances are of interest with regard to this phase of the subject. Cumarin (0.0009 per cent) produced a reaction following 8.4 seconds; and the latent period for quinine (0.0007 per cent) was 9.2 seconds. A mixture containing both 0.0009 per cent cumarin and 0.0007 per cent quinine gave a latent period value exactly the same as that of cumarin alone, 8.4 seconds; that is, the latent period measured was that of the substance (cumarin) in the mixture which alone would produce the shorter reaction time. In another experiment the latent period for cumarin (0.0013 per cent) was 6.05 seconds, and that for quinine (0.001 per cent) was 5.85 seconds. The solution consisting of both 0.0013 per cent cumarin and 0.001 per cent quinine gave a latent period, within a small error, the same as that

of quinine alone. The two substances stimulate entirely separately. Both reactions probably took place, but only the shorter one could be measured.

It is to be expected that, if the two substances act on the same sensory ending, the effect of such a mixture would be additive and therefore cause reaction following a latent period shorter than that of either alone. Such is the case when mixtures of such salts as KCl and NaCl are employed. Two solutions were made up as follows: KCl, 0.1 M.; and NaCl, 0.5 M. The latent periods of the reaction to these and to mixtures of the two solutions were as follows:

	Seconds
NaCl	3.69
1 part KCl, 2 parts NaCl	3.64
1 part KCl, 1 part NaCl	3.59
2 parts KCl, 1 part NaCl	3.52
KCl	3.50

The effect of the two salts in the above case was additive. It is possible to keep the latent period constant by replacing a part of the KCl with the proper amount of NaCl. However, this is not true in the case of mixtures of quinine and cumarin, or of cumarin and NaCl.

Crozier (1916) demonstrated the physiological antagonism between the salts of certain univalent and bivalent cations in the stimulation of the frog's foot. Tests with mixtures of NaCl and $MgCl_2$ on stimulation of the oyster failed to demonstrate any antagonism. However, the high proportion of these salts in sea water would suffice to prevent any considerable effect of such antagonism. These tests, nevertheless, are of some interest for the results seem to throw some light upon the question of changing latent periods.

In Table 1 data are presented to show the results of an attempt to find the latent period due to mixtures of NaCl and $MgCl_2$ each of which had approximately the same effect. It will be observed that most of the values are between 2.45 and 2.65 seconds, but that certain of them are about one second higher. On one day the experiments with NaCl were made and the latent period was of the high level. On the next day the latent period for $MgCl_2$ was about the same. On the third day a mixture was employed and the latent period was a full second lower. It appeared as if the effect of the mixture had been increased, but a series of tests with NaCl gave low values also. During the following two days the latent periods of the reaction to solutions of a single salt or to mixtures remained likewise low. Two days later, however, the reaction time to $MgCl_2$ was again high, but that to a mixture was low.

TABLE 1.—*Latent periods of reaction to mixtures of NaCl (0.5 M) and $MgCl_2$ (0.5 M)*

Date	Time	Salts	Average latent periods	Temperature	Latent period level
				°C.	
Feb. 1	10-11 a. m.	NaCl	3.67	8.7	High.
Feb. 2	2-3 p. m.	$MgCl_2$	3.65	10.3	Do.
Feb. 3	10-11 a. m.	NaCl, 50 per cent; $MgCl_2$, 50 per cent	2.69	9.5	Low.
	3-4 p. m.	NaCl	2.58	11.5	Do.
Feb. 4	11-12 m.	$MgCl_2$	2.80	12.3	Do.
	3-4 p. m.	NaCl, 50 per cent; $MgCl_2$, 50 per cent	2.59	13.0	Do.
Feb. 6	11-12 m.	NaCl, 25 per cent; $MgCl_2$, 75 per cent	2.43	11.0	Low.
	4-5 p. m.	NaCl	2.45	10.5	Do.
Feb. 7	10-11 a. m.	$MgCl_2$	3.61	12.5	High.
	3-4 p. m.	NaCl, 10 per cent; $MgCl_2$, 90 per cent	2.40	12.8	Low.

The table shows well the confusion given rise to by such fluctuations. Obviously temperature was not responsible for such behavior. It is clear that there are in this case two different latent period levels which appear. The reason for the change from one to the other is puzzling.

The existence of two latent period levels of a different nature was shown in the tests with NaOH. (Figs. 8 and 9.) In this case two typical curves crossed each other, and it was suggested that one curve represented the response to Na ions and the other that to OH ions. Crozier made studies of the sensory response of earthworms to acids (1918a) and to alkalies (1918b). His method was to measure the time required for withdrawal of the worm from the test solution. Certain of his logarithmic curves (1918b, fig. 3) show sharp breaks suggesting the existence of two intersecting curves. His method was not adapted to show whether each curve was continuous in both directions beyond the intersection. The response studied—locomotion for a certain distance—represents not a simple response but all of the neuromuscular activity involved in locomotion.

Crozier found it necessary to subtract from the reaction time a figure representing "the mechanical resistance to, or disadvantage of, its method of progression," in order for the effect, $\left(\frac{1}{\text{R. T.}}\right)$, to be directly proportional to the concentration. After subtraction of this factor the logarithmic curves make an angle of 45° with the y-axis. In the present experiments, also, it was found that a constant must be subtracted from the latent period values in order for the equation, $C \times T = K$, to obtain. While in the case of the complicated locomotor activity of the worm it is conceivable that the "mechanical disadvantage" might account for this factor, it appears improbable that such an explanation would suffice for the comparatively simple retraction of the delicate tentacles of the oyster. More likely appears the hypothesis that the layer of mucus constantly present serves to impede the penetration of the molecules of stimulating chemical. Further experiments are under way to clear up this point.

SUMMARY

(1) The tentacles on the mantle of the oyster react to chemical irritation by retracting sharply. They are sensitive to odorous compounds, such as cumarin, and to salts, acids, alkalies, and quinine, but show no clear reaction to cane sugar.

(2) Graphs plotted to show the relationship between concentration and latent period indicate that the effect, considered to be represented by the reciprocal of the latent period, is directly proportional to the concentration. However, in order for this to be the case it is necessary to subtract a constant from the latent period values. This constant is supposed to represent the impedence due to mucus covering the receptors.

(3) In certain cases it was found that the latent period fluctuated between two levels. For a series of concentrations the values obtained would fall into two well-separated and distinct curves, mathematically comparable. This does not appear to be due to fatigue or to variations in temperature.

(4) The latent period values for solutions of sodium hydroxide in sea water appear to be most clearly represented by two intersecting curves. Expressed logarithmically one of these makes an angle of less than 45° with the horizontal and may indicate the response to sodium cations; the angle of the other is approximately 45° and may

represent the effect of OH ions. Similarly plotted, the results for KOH fall into a single curve making an angle of less than 45°. If this interpretation is correct, the concentration of OH ions is directly proportional to the effect, but for the effect of ions of Na and K a factor must be introduced, as in the case of the salts, for this relationship to hold.

(5) The response of the adductor muscle to stimulation of the tentacles bears a relationship to concentration similar to that of the tentacular reaction, but the reaction time is longer.

(6) When mixtures of cumarin and quinine are employed the latent period of the reaction observed is the same as that of the substance which, alone, would produce reaction after the shorter latent period. The two substances act independently, one neither enhancing nor inhibiting the effect of the other.

(7) Mixtures of two salts, such as NaCl and KCl or NaCl and $MgCl_2$, are additive in effect and presumably act on the same endings in the same manner.

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FLUCTUATIONS IN THE SUPPLY OF HERRING, *CLUPEA PALLASII*, IN PRINCE WILLIAM SOUND, ALASKA

By George A. Rounsefell, Ph. D., *Junior Aquatic Biologist*, and Edwin H. Dahlgren, *Junior Aquatic Biologist*

CONTENTS

INTRODUCTION [1]

The herring fishery of Prince William Sound has been marked by fluctuations in the abundance, size, and quality of fish. The effect on the industry has been widespread and harmful. Companies have lost large sums owing to temporary fluctuations in abundance or to changes in the proportions of large herring suitable for pickling. The stabilization of the yield of this fishery constitutes an important economic problem for solution.

The main causes for these fluctuations in abundance are twofold: First, inequality in the numerical strength of the annual increments to the population proceeding from each year class; and second, insufficient numbers of older fish, caused by a too intensive fishery. The first cause of fluctuations can not well be controlled, as the success or failure of a spawning appears to depend chiefly on the surface temperature of the ocean. Knowing that such fluctuations in the annual increments to the population are bound to occur, it is obvious that the fishery can not be stabilized unless it draws chiefly upon the older fish, which should form a reservoir of sufficient size to be able to bridge gaps of a few years with very small increments to the population, without causing too large or too sudden a decrease in the yield of the fishery. This paper deals chiefly with the problem of securing this optimum yield.

The methods of collecting and analyzing the data are similar to those given in a previous report by the senior author (Rounsefell, 1930).

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[1] The authors wish to acknowledge the criticism of Dr. Frederick A. Davidson on the section on local populations. Submitted for publication, Oct. 14, 1931.

THE FISHERY

EARLY HISTORY AND DEVELOPMENT

Although the Prince William Sound herring fishery originated at a comparatively recent date, only a few scattered references indicate when it had its inception. In 1913 the Prince William Sound Fish Co. reported to the United States Bureau of Fisheries pickling 20,000 pounds of herring, and selling 1,600 pounds as halibut bait at Kiniklik. In 1914 the Pacific Fishermen credits this company with 42,800 pounds of pickled herring, and also refers to a company in Valdez handling herring exclusively. In 1915 the only reference in the Pacific Fishermen is of a shipment of 2,400 pounds of herring from Seward. In 1916 the same journal mentions the establishment of a herring saltery by J. A. Linseth at Kiniklik.

In 1917, to offset the shortage of imported herring caused by the World War, the United States Bureau of Fisheries sent Aug. H. D. Klie and several assistants to Alaska to introduce the Scotch method of curing herring, hoping thereby to prepare a commodity acceptable to the general trade. Clarence L. Anderson was assigned to the Prince William Sound region. In that year 137,400 pounds of pickled herring (229,458 raw) were recorded from Cordova, Kiniklik, and Evans Bay. In addition, a cold storage plant was built at Seward that sold 125,000 pounds of herring as halibut bait.

The Prince William Sound fishery can really be said to date from 1918. Owing to the World War, prices of foodstuffs were high. As a consequence, in that year, plants were built at Thumb Bay, Latouche, and Evans Bay. For the first time operations were begun in the early summer instead of waiting until the fish schooled near the spawning grounds in the late fall and winter, at which time, although the fish are more easily caught, they are too thin to be of much value.

The 1918 pack was, in general, poorly prepared. As a result the operators had difficulty in marketing, and prices were low. However, the larger fish taken in Prince William Sound gave the packers in this district an advantage over those in southeastern Alaska, as the buyers would not accept the smaller selections. Thus in southeastern Alaska the quantities of herring used for pickling fell from 21,000,000 pounds in 1918 to 5,400,000 pounds in 1919, while in Prince William Sound 7,200,000 and 7,100,000 pounds were used in the two years.

The canning of kippered herring was initiated in 1916 in southeastern Alaska, reaching a peak in 1919 of 5,000,000 pounds in southeastern Alaska and 2,600,000 pounds in Prince William Sound. All efforts to find a satisfactory market failed, however, and this project was abandoned.

In 1920 two reduction plants were installed to handle the waste from the pickling operations (Table 1), utilizing 10,400,000 pounds of herring.

TABLE 1.—*Capacity of Prince William Sound reduction plants in tons of fish used per hour*

Location of plant	Years operated										
	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
Thumb Bay	2		2	2	2	2	2	2	2	2	2
Port Ashton	4	4	4	4	4	4	4	4	4		
Port Benny				2	2	2	2	2			
Crab Bay					2	2	2	2	2	2	10
Sawmill Bay					2	2	2	2	2	2½	2½
Drier Bay					2	2	2	[1] 2			
Port Benny						4	4	4		[2] 4	4
All plants	6	4	6	8	14	18	18	[1] 17	10	[2] 8½	18½

[1] Drier Bay plant operated for only few days early in season, so rated at one-half capacity in the total for all plants.
[2] Port Benny plant used only one seine boat, so rated at one-half capacity in the total for all plants.

Figure 1.—Schooner *Alice Cooke*, a typical floating herring saltery in Evans Bay in June, 1928. Later in the season she operated in the Kodiak-Afognak and Aleutian Islands districts

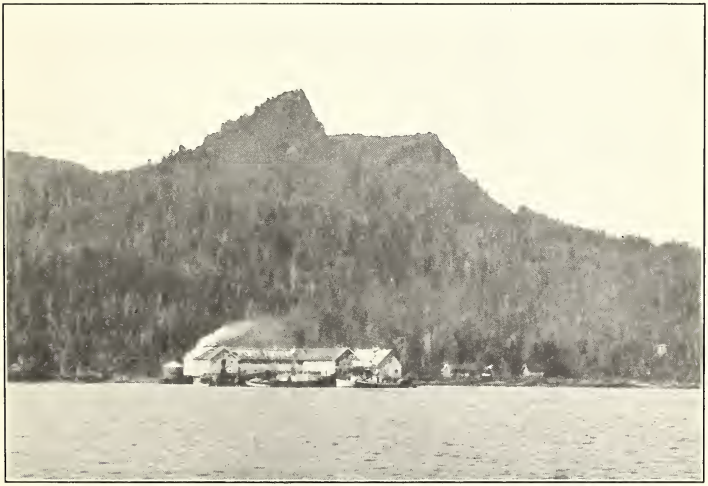

Figure 2.—Saltery and reduction plants at Port Benny, Evans Bay. Built in 1921 as a saltery, a 2-ton reduction unit was added in 1923 and a 4-ton reduction unit in 1925. Taken in July, 1926

In 1921 the prices of fish oil and fish meal were so low that the Thumb Bay plant did not operate the reduction unit, and the Port Ashton plant utilized but 1,900,000 pounds in this manner. The amounts used for pickling increased, however, from

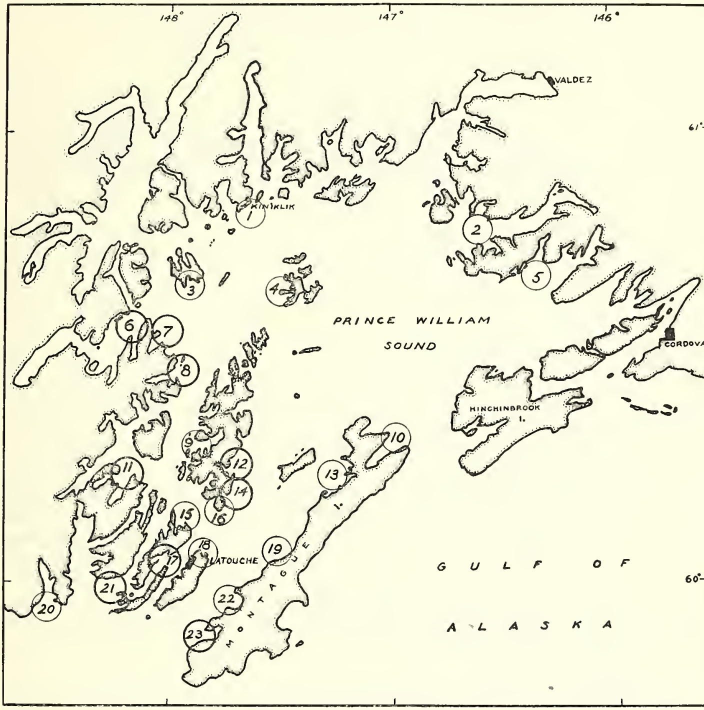

FIGURE 3.—Past and present fishing grounds of Prince William Sound. The more important grounds are indicated by heavier circles. 1, Kiniklik; 2, Port Fidalgo; 3, Perry Island; 4, Naked Island; 5, Port Gravina; 6, McClure Bay; 7, Main Bay; 8, Eshamy Bay; 9, Drier Bay; 10, Zaikoff Bay; 11, Whale Bay; 12, Snug Harbor; 13, Port Chalmers; 14, Hogan Bay; 15, Shelter Bay; 16, Point Helen; 17, Evans Bay; 18, Sleepy Bay; 19, Glacior Bay; 20, Puget Bay; 21, Elrington and Prince of Wales Passages; 22, Hanning Bay; and 23, Macleod Harbor

9,200,000 pounds in 1920 to 16,700,000 pounds in 1921, in spite of the loss by fire of the W. J. Imlach plant at Port Benny in Evans Bay.

The success met with in marketing the 1921 pickled herring pack resulted in more operators establishing plants in this district in 1922. The number of plants increased from 5 in 1921 to 9 in 1922 (a very small amount was also pickled at Cordova), and the number of purse seine boats employed increased from 9 to 18. (Table 2.) The prices of fish oil and fish meal had not wholly recovered from their 1921 slump, and only 6,800,000 pounds of herring were diverted for this purpose.

This amount must be considered as waste incidental to pickling operations. The companies were all attempting to make as large a pack as possible of pickled herring, 37,100,000 pounds being so utilized.

TABLE 2.—*Number of boats fishing in Prince William Sound weighted according to per cent of season's catch taken during portion of season they fished in the sound*

Year	Actual number of boats						Number of boats weighted by per cent of total average seasonal catch taken during period each boat fished in Prince William Sound [1]
	Fishing only in Prince William Sound	Fishing in Prince William Sound until opening of season at Kodiak-Afognak district	Fishing in Prince William Sound until opening of season at Kodiak-Afognak district and returning about Sept. 3	Fishing in Prince William Sound until leaving for Cook Inlet about Aug. 4	Fishing in Prince William Sound until leaving for Dutch Harbor about Aug. 4	Fishing in Prince William Sound until leaving for Dutch Harbor about Aug. 4 and returning about Sept. 12	
1918	10						10
1919	7						7
1920	8						8
1921	9						9
1922	18						18
1923	20						20
1924	13	4	1	7			18.29
1925	12	6	2	6			13.20
1926	10	8	1	2			10.48
1927	7	7		7			12.31
1928	6	15		2	1	2	12.59
1929	10						7.23
1930	8						5.78

[1] Per cent taken during each part of the season was computed from the table of the average catch per boat per 10-day period.

A considerable quantity of the large 1922 pack still remained on the market in 1923. As a consequence, less effort was made to pickle herring, the amount so used decreasing from 37,100,000 pounds in 1922 to 19,700,000 pounds in 1923. The decline in the amount pickled may be ascribed partially to scarcity of large pickling fish during the late summer, as by this time a demand for 1923 fish had become apparent and the packers made belated efforts to obtain a pack. A small reduction plant was installed in 1923 at Port Benny, increasing the total capacity of all of the reduction units from 6 to 8 tons of raw fish per hour. Owing also to less interest in pickling, and to complete recovery of oil and meal prices from the 1921 slump, the poundage used for reduction increased from 6,800,000 pounds in 1922 to 13,900,000 pounds in 1923.

Since 1924 the development of the Prince William Sound herring fishery has been closely linked with that of the Kodiak-Afognak and Cook Inlet districts. In 1922 the three largest operators in Prince William Sound sought for pickling herring farther to the westward. The W. J. Imlach Packing Co. established a saltery in the town of Uzinki, near Kodiak. The San Juan Fishing & Packing Co. located a saltery in Uganik Bay on the Shelikof Strait side of Kodiak Island. The Franklin Packing Co. salted herring aboard the schooner *Henry Wilson*, and built a saltery ashore at Port McKinley in Izhut Bay, Afognak Island. These ventures were not very successful in 1922. In 1923, W. J. Imlach discovered herring in large quantities in Red Fox Bay on Afognak Island, and the Fidalgo Island Packing Co. at Port Graham met with success in using purse seines in Cook Inlet during the summer months, while formerly all of the fine, large Cook Inlet fish had been taken with gill nets late in the fall when the fish were not sufficiently fat to be suitable for the Scotch cure.

In 1924 several of the packers in Prince William Sound prepared to fish on a large scale in Red Fox Bay and in Cook Inlet. From 1924 until 1928, inclusive, many of the seine boats did a great deal of moving about during the season, fishing in Prince William Sound, Cook Inlet, the Kodiak-Afognak district, and, in 1928, at Unalaska in the Aleutian Islands. This renders it rather difficult to understand the fluctuations that occurred in the catch during the period from 1924 to 1928, inclusive. These changes are treated more fully in the section on the condition of the supply.

FISHING GROUNDS

Prior to 1923 accurate records of the fishing grounds are lacking. Some knowledge of the grounds fished and amounts and sizes of fish taken has been gathered from various sources, and, although fragmentary, it is presented for what it is worth. (See fig. 4.)

Most of the 1918 herring were seined in Evans Bay (Evans Island area). In 1919 a large share of the pack was caught in the Evans Island area during July, some small herring were taken in the southern Knight Island area during June, and a quantity of large fat herring were caught in Whale Bay from mid-September through October.

During 1920 the southern Knight Island and Evans Island areas produced large quantities of summer herring. From mid-September through October large quantities of herring were taken in Whale Bay (two companies took 7,000 barrels). These were mostly small and used for reduction. One packer reports that herring were also plentiful in Main Bay, but he considered it too distant for profitable fishing.

Only a few thin fish were taken during June in 1921. From about the 4th of July until the 1st of August herring were taken off Procession Rocks in the Evans Island area. Herring were scarce during August and until the last of September. From then on through October large quantities of herring of mixed sizes were taken in both Whale Bay and Main Bay. Very late in the fall several loads of herring were caught in McClure Bay (Main Bay area).

For 1922 we have accurate locality records of a company that caught about 8.7 per cent of the total catch. This company took 50.7 per cent of its catch from the Evans Island area, 3.9 per cent from southern Knight Island, 5.5 per cent from the southwest Montague Island area, and 39.9 per cent from the Main Bay area. Other operators, however, fished but little in the vicinity of Evans Island, taking about 50 per cent of their catch from Macleod Harbor and Hanning Bay on the southwest end of Montague Island. All packers agree that the 1922 herring were the largest ever taken in the sound, rivalling the large Kodiak-Afognak district herring taken in Red Fox Bay from 1923 to 1927.

For 1923 and succeeding years accurate locality records are available on a sufficient portion of the catch to permit allocation of the whole catch to various localities with a high degree of confidence. (Table 3.) The most striking feature of Table 3 is the large percentage of the catch taken in the vicinity of Evans Island. It is at once apparent from the table and from the foregoing discussion that this area never failed to contribute a share of the catch. The next largest producing areas, southern Knight Island and southwestern Montague Island have, on the contrary, been extremely erratic.

In framing any regulations to govern these fisheries it is imperative that the relative importance of each fishing ground be kept clearly in mind.

FIGURE 4.—Western portion of Prince William Sound, showing the herring plants and the present fishing grounds

TABLE 3.—*Catch in various localities in Prince William Sound*

[In thousands of pounds]

Area fished	Year								Area totals	Average per cent in each area
	1923	1924	1925	1926	1927	1928	1929	1930		
Evans Island	26,803	11,931	14,364	7,373	7,197	1,832	3,104	8,985	81,589	50.7
Southwestern Montague Island	175			1,247	209	12,533	7,151	20,496	41,811	26.0
Southern Knight Island	4,134	5,199	8,896	619		711	2,270	104	21,933	13.6
Main Bay	3,293	921	3,564	1,539	2,026				11,343	7.0
Northeastern Montague Island							1,149	1,704	2,853	1.8
Whale Bay	631					61			692	.4
Naked Island			381		60				441	.3
Perry Island								326	326	.2
Annual total	35,036	18,051	27,205	10,778	9,492	15,137	13,674	31,615	160,988	
Per cent of catch for which localities are known	30	30	15	20	70	50	65	100		

LOCAL POPULATIONS

In making a detailed study of the fluctuations in abundance, it is of great advantage to know whether the catch is being drawn from one or from several populations since the commercial catch may not be drawing proportionately on each population and each population may not be securing proportional annual increments. Owing to the difficulty of securing sufficient numbers of accurate counts of the fin rays and gill rakers, and to the great variability in the body proportions (which is especially noticeable in purse-seined material), the analysis has been based wholly on vertebral counts.

Before comparing the vertebral counts from the various localities it is interesting to know what the causes are for variability in this character, whether they are genetic or environmental. For this purpose the counts from all localities in Prince William Sound for each year class (fish spawned the same year) from 1919 to 1927, inclusive, were treated as a single distribution and the mean computed. These means (Table 5) were correlated with the average air temperatures for March, April, May, and June from Seward, Cordova, and Latouche. (Table 4.)

TABLE 4.—*Mean annual air temperatures of the combined months of March, April, May, and June from Seward, Cordova, and Latouche*

Year	U. S. Weather Bureau data				U. S. Coast and Geodetic Survey data [1]
	Seward	Cordova	Latouche	Average	Seward
1908	41.40			41.40	
1909	39.88			39.88	
1910	38.43	40.55		39.49	
1911	38.80	37.70		38.25	
1912	42.35	43.15		42.75	
1913	41.73	43.38		42.56	
1914	41.88	43.50		42.69	
1915	46.70			46.70	
1916	40.30			40.30	
1917	44.25		39.83	42.04	
1918	40.45		40.07	40.26	
1919	40.63	39.50		40.07	
1920	38.35	38.95	39.63	38.98	
1921	41.43	42.23		41.83	
1922	38.98	38.18		38.58	
1923	44.33	40.13		42.23	
1924	42.23	42.43	42.10	42.25	
1925		40.53	40.15	40.34	
1926		46.23	46.18	46.20	45.90
1927		40.20	41.05	40.63	40.26
1928		40.90	41.62	41.26	41.94
1929					40.06
1930					41.31

[1] 5.40° have been subtracted from the U. S. Coast and Geodetic Survey temperatures to make them comparable to Weather Bureau data. This allowance has been made for the difference in the time of day at which the temperatures were taken. The correction was empirically determined by taking the average difference between the two series for 1926, 1927, and 1928.

Two sources were available for air (and water) temperatures: The Climatological Data, published by the United States Weather Bureau since 1908, and daily air and water temperatures (unpublished) taken at Seward by the United States Coast and Geodetic Survey since June, 1925.

Since only air temperatures are available for these months previous to 1926, a correlation was made between the air and surface water temperatures which were taken daily at the same hour at Seward, to determine the degree of relationship existing between the two. These data, covering a period of 5 years, gave a coefficient of correlation of 0.93; to test the significance of this relationship t was computed, and was found to be 11.017, when a t of only 2.878 was equivalent to a probability of 0.01, proving the correlation to be highly significant. This shows that air temperatures give an accurate index to surface-water temperatures, and that the use of air temperatures as an index to conditions on the spawning beds is justified.

Unfortunately the series of air temperatures for Cordova, Latouche, and Seward are not complete. (Table 4.) Figure 5 shows, however, that the temperatures for these points are comparable from year to year. The temperatures for the Prince William Sound area, as given in the following discussion, are averaged from those which are available for each year from these three localities. The dotted line in Figure 5 shows the air temperatures for Seward, taken from unpublished United States Coast and Geodetic Survey data (from which 5.40 degrees have been subtracted to make them comparable to the United States Weather Bureau statistics).

The means of the vertebral counts of the various year classes were therefore correlated with the average air temperatures for March, April, May, and June from Seward, Cordova, and Latouche by the formula:

$$r=\frac{S(xy)}{\sqrt{S(x^2)\cdot S(y^2)}} \qquad \text{(Fisher, 1930)}$$

giving a coefficient of correlation of -0.85. The significance of this coefficient was tested by the method of Fisher for small samples (1930, p. 159) if n' be the number of pairs of observations:

$$t=\frac{r}{\sqrt{1-r^2}}\cdot\sqrt{n'-2}$$

giving a t of 5.807 which has a probability much less than 0.01 (Fisher's tables) showing that the coefficient of correlation -0.85 is definitely significant.

TABLE 5.—*Correlation of air temperature and average number of vertebræ in Prince William Sound*

Year	1919	1920	1921	1922	1923	1924	1925	1926	1927
Air temperature [1]	40.07	38.98	41.83	38.58	42.23	42.25	40.34	46.20	40.63
Mean of vertebræ	52.870	53.150	52.836	52.963	52.869	52.719	52.821	52.456	52.784
Number of specimens:									
Elrington Passage	12	11	107	73	58	70	9	343	6
Naked Island	4	3	45	16	3	3	2	-------	-------
McClure Bay	7	1	74	27	32	29	2	-------	-------
Eshamy Bay	-------	5	56	14	8	1	-------	-------	-------
Macleod Harbor	-------	-------	4	5	28	142	50	599	34
Snug Harbor	-------	-------	-------	-------	1	6	16	350	7
Port Chalmers	-------	-------	-------	-------	-------	1	2	94	3
Zaikoff Bay	-------	-------	-------	-------	-------	2	-------	35	7
Port Fidalgo	-------	-------	-------	-------	-------	4	5	54	-------
Glacier Bay	-------	-------	-------	-------	-------	5	5	168	19
Shelter Bay	-------	-------	-------	-------	-------	-------	1	86	9
Point Helen	-------	-------	-------	-------	-------	-------	1	70	2
Sleepy Bay	-------	-------	-------	-------	-------	-------	2	173	24
Total	23	20	286	135	130	263	95	1,972	111

[1] Average for March, April, May, and June from Seward, Cordova, and Latouche.

As the herring in Prince William Sound spawn and the eggs develop during the months from March to June, inclusive, the inference to be drawn is obvious. The differences in the vertebral count found between different year classes are probably due entirely to environment. Also any significant differences found between herring of the same year class taken in different localities in Prince William Sound may be, and probably are, simply an expression of environmental differences on the spawning grounds.

From the foregoing it is clear that comparisons between the vertebral counts of different localities are valid for showing population differences (in the absence of exact knowledge as to the conditions on the spawning grounds) only when the com-

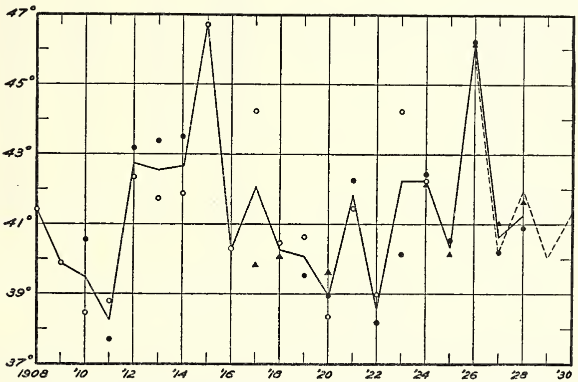

FIGURE 5.—Average mean annual air temperatures for the combined months of March, April, May, and June for Seward, Cordova, and Latouche. Solid line is from "Climatological Data" of the U. S. Weather Bureau. Dotted line (see text) from unpublished data taken by the U. S. Coast and Geodetic Survey at Seward only. Circles indicate Seward temperatures; dots, Cordova temperatures; triangles, Latouche temperatures taken by Weather Bureau

parisons are between fish of the same year class. It is also clear that the absence of significant differences in the vertebral count between samples of the same year class does not necessarily indicate that the populations of any two localities are identical. Similarity of conditions on the spawning grounds may cause the lack of a significant difference between fish from two localities.

Comparisons of vertebral count distributions of fish of the same year class from neighboring localities are given in Table 6. Any two means are compared by dividing their difference by the standard error estimated by the formula

$$\sigma=\sqrt{\frac{S(x-\bar{x})^2+S(x'-\bar{x}')^2}{n_1+n_2}\left(\frac{1}{n_1+1}+\frac{1}{n_2+1}\right)}$$

if $x_1, x_2 \ldots, x_{n_1+1}$ and $x'_1, x'_2 \ldots x'_{n_2+1}$ be two samples, and

$$\bar{x}=\frac{1}{n_1+1} S\,(x),\ \bar{x}'=\frac{1}{n_2+1} S\,(x')$$

TABLE 6.—*Comparisons of the means of the vertebral counts of each year class in Prince William Sound*

Localities compared	Year class	Difference between means	Summation of populations	Standard error of difference between means	Difference between means divided by standard error
McClure Bay and Naked Island	1921	0.322	119	0.1010	3.19
Do	1922	.060	33	.1949	.31
McClure Bay and Eshamy Bay	1921	.232	130	.0990	2.34
Do	1922	.328	41	.1811	1.81
Naked Island and Eshamy Bay	1921	.090	101	.1233	.73
Do	1922	.268	30	.2341	1.14
Naked Island and Elrington Passage	1921	.154	152	.1183	1.30
Do	1922	.221	89	.2010	1.10
Snug Harbor and Point Helen	1926	.020	420	.0959	.21
Snug Harbor and Port Chalmers	1926	.094	444	.0869	1.08
Snug Harbor and Glacier Bay	1926	.052	518	.0685	.76
Snug Harbor and Port Fidalgo	1926	.016	404	.1086	.15
Zaikoff Bay and Port Fidalgo	1926	.032	89	.1649	.19
Zaikoff Bay and Port Chalmers	1926	.142	129	.1520	.93
Glacier Bay and Port Chalmers	1926	.146	262	.0917	1.59
Glacier Bay and Sleepy Bay	1926	.061	341	.0782	.78
Do	1927	.053	43	.1975	.27
Glacier Bay and Macleod Harbor	1926	.076	767	.0620	1.23
Do	1927	.465	53	.2311	2.01
Glacier Bay and Point Helen	1926	.032	238	.0969	.33
Macleod Harbor and Sleepy Bay	1926	.015	772	.0624	.24
Do	1927	.412	58	.2260	1.82
Macleod Harbor and Elrington Passage	1923	.276	86	.1694	1.63
Do	1924	.061	212	.0997	.61
Do	1926	.024	942	.0502	.48
Sleepy Bay and Elrington Passage	1926	.009	516	.0721	.12
Sleepy Bay and Shelter Bay	1926	.073	259	.0957	.76
Sleepy Bay and Point Helen	1926	.029	243	.1025	.28
Shelter Bay and Elrington Passage	1926	.082	429	.0922	.89
Shelter Bay and Point Helen	1926	.102	156	.1068	.96
Port Chalmers and Point Helen	1926	.114	164	.1118	1.02

The desirability of calculating the standard error of the difference by a pooled estimate of the variance is explained by Fisher (1930, p. 108), who says:

> It may be noted in connexion with this method, and with later developments, which also involve a pooled estimate of the variance, that a difference in variance between the populations from which the samples are drawn will tend somewhat to enhance the value of t [difference between means divided by its standard error] obtained. The test, therefore, is decisive, if the value of t is significant, in showing that the samples could not have been drawn from the same population; but it might conceivably be claimed that the difference indicated lay in the variances and not in the means. The theoretical possibility, that a significant value of t should be produced by a difference between the variances only, seems to be unimportant in the application of the method to experimental data; as a supplementary test, however, the significance of the difference between the variances may be tested directly by the method of paragraph 41.

These comparisons give two statistically significant differences between neighboring localities which might be construed as indicating the independence of the stocks of herring of the localities between which these significant differences occur. However, these differences can not be accepted as valid without a knowledge of the homogeneity of the material. To this end Table 7 is presented showing the means of the 12 samples of vertebral counts from herring of the 1926 year class caught at Macleod Harbor. These samples do not show any statistically significant differences between each other.

TABLE 7.—*Vertebral count samples of the 1926-year class from Macleod Harbor*

Date taken	Mean	Number of specimens	Sum of squares of deviations from mean	Standard error of mean	Date taken	Mean	Number of specimens	Sum of squares of deviations from mean	Standard error of mean
June 28, 1928	52.545	33	20.182	0.136	July 18, 1930	52.548	42	20.405	0.107
July 5, 1928	52.333	12	4.667	.180	July 19, 1930	52.553	47	41.617	.137
July 8, 1929	52.406	96	45.156	.070	Do	52.349	43	19.767	.103
July 9, 1929	52.380	71	40.732	.090	July 21, 1930	52.350	40	13.100	.090
July 19, 1929	52.477	88	37.955	.070	July 22, 1930	52.415	41	19.951	.109
July 20, 1929	52.600	45	14.800	.085					
July 22, 1929	52.366	41	17.512	.102	Total	52.442	599	305.763	.029

Since the material is apparently homogeneous McClure Bay, which differs by 3.19 standard errors from Naked Island and 2.34 standard errors from Eshamy Bay, giving probabilities of 0.002 and 0.02, respectively, may have an independent stock of herring, but can not be definitely said to differ without further data.

CONDITIONS OF THE SUPPLY

FACTORS INFLUENCING THE DETERMINATION OF ABUNDANCE

The principal aim of this investigation has been to determine the trend of abundance as influenced by the present intensive fishery. Our determinations of this trend are, and must be, imperfect, as the only index to the abundance of the herring is contained in the records of the commercial fishery. Even supposing this fishery obtained a representative sample of the total population (which it does not, due to selective schooling and the selective action of the gear used) there would still be some doubt as to the adequacy of our sampling of this commercial catch. Even if the size and age composition of the population were accurately known, there would still be the question of its abundance. The only available unit of fishing effort—the seine boat—is not standardized; and, if it were, we would still be confronted with changes in the availability of the fish at different seasons, and in fluctuations of this availability at the same period in different years owing to factors not yet understood. In spite of these handicaps the following analysis has been made, using the available data, and a few important facts have been discovered.

As aforementioned, the changes in the abundance of the supply of fish may be caused by natural conditions such as the presence of dominant year classes, or they may be caused by the artificial conditions brought about by an intensive fishery. The availability of the fish, apart from their abundance, may be subject to seasonal variations, and is influenced by regulations restricting the length of the season or limiting the areas to be fished. The intensity of the fishery depends not only on the number, size, and efficiency of the fishing boats, but also indirectly on the size and type of shore plants, inasmuch as the quantity, size, and condition of the fish on delivery to the plant is dependent on the purpose for which the fish are to be used, and governs the effort expended in securing them. Considerable difficulty is met with in showing the relation existing between these various factors and the total catch from year to year, on account of the data being insufficient, especially for the earlier years of the fishery, to give a proper measure of the effects of each factor.

SEASONAL CHANGES IN AVAILABILITY

Among the causes for fluctuations in the yield of the fishery is a seasonal variation in the availability of the supply of fish. Figure 6 shows the average catch per boat per 10-day period, computed for data from 1923 to 1930, inclusive. The first and highest mode of 938 barrels occurs during July, after which there is a steady decline until about the 20th of September, when a second rise becomes apparent, reaching a

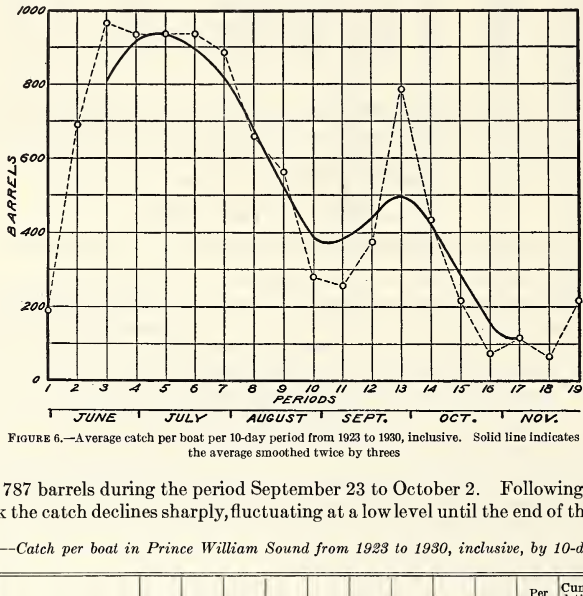

FIGURE 6.—Average catch per boat per 10-day period from 1923 to 1930, inclusive. Solid line indicates the average smoothed twice by threes

mode of 787 barrels during the period September 23 to October 2. Following this second peak the catch declines sharply, fluctuating at a low level until the end of the season.

TABLE 8.—*Catch per boat in Prince William Sound from 1923 to 1930, inclusive, by 10-day periods*

Period No.	Date	1923	1924	1925	1926	1927	1928	1929	1930	Average	Per cent of total	Cumulative percentage	Average smoothed twice by 3's
1	May 26–June 4	(1)	190	(1)	(1)	(1)	(1)	(1)	(1)	190	2.0	2.0	
2	June 5–June 14	438	941	(1)	(1)	(1)	(1)	(1)	(1)	690	7.2	9.2	
3	June 15–June 24	1,413	1,741	(1)	(1)	323	382	(1)	(1)	965	10.1	19.3	808
4	June 25–July 4	1,469	1,221	1,168	611	274	308	[2] 1,230	[2] 1,199	935	9.7	29.0	915
5	July 5–July 14	1,350	1,205	1,295	352	308	344	902	1,738	937	9.8	38.8	934
6	July 15–July 24	1,513	392	1,102	336	99	862	965	2,232	938	9.8	48.6	894
7	July 25–Aug. 3	1,031	767	468	195	139	702	1,212	2,559	884	9.3	57.9	816
8	Aug. 4–Aug. 13	1,025	17	57	86	513	633	1,090	1,837	657	6.8	64.7	676
9	Aug. 14–Aug. 23	1,413	50	79	90	46	782	483	1,554	562	5.9	70.6	522
10	Aug. 24–Sept. 2	338	0	348	0	6	174	427	950	280	2.9	73.5	390
11	Sept. 3–Sept. 12	0	0	417	708	0	255	511	167	257	2.7	76.2	381
12	Sept. 13–Sept. 22	130	0	83	44	93	772	216	1,655	374	3.9	80.1	436
13	Sept. 23–Oct. 2	888	333	550	16	482	601	0	3,428	787	8.2	88.3	494
14	Oct. 3–Oct. 12	69	0	75	87	492	679	213	1,844	432	4.6	92.9	416
15	Oct. 13–Oct. 22	122	30	0	312	159	504	28	564	215	2.2	95.1	284
16	Oct. 23–Nov. 1	0	0	0	0	280	234	0	(1)	73	.8	95.9	153
17	Nov. 2–Nov. 11	21	0	0	0	[3] 300	0	500	(1)	117	1.2	97.1	117
18	Nov. 12–Nov. 21	6	0	(4)	(4)	(1)	(4)	250	(1)	[5] 64	.7	97.8	
19	Nov. 22–Dec. 1	336	83	(1)	(1)	(1)	(1)	225	(1)	215	2.2	100.0	

[1] No fishing.
[2] Four days fishing weighted to equal 10 days.
[3] Three days fishing weighted to equal 10 days.
[4] Four days fishing.
[5] When computed, the three 4-day open periods of 1925, 1926, and 1929 (totaling 12 days) during which time no fish were taken, were considered as one period.

Graphing these seasonal variations in yield in a different way, Figure 7 shows the cumulative per cent curve of the average daily catch per boat computed by 10-day periods. During the first 6 of the 19 periods (from May 26 to July 24), 49 per cent of the season's catch is taken; during the last 6 periods (from Oct. 3 to Dec. 1) only 7 per cent. Approximately 75 per cent of the seasonal catch is taken before the 1st of September.

The histogram of Figure 7 shows the first differential of the cumulative percentage curve, giving the percentage increments occurring during each period. The largest increments occur from the third through the seventh periods, remaining

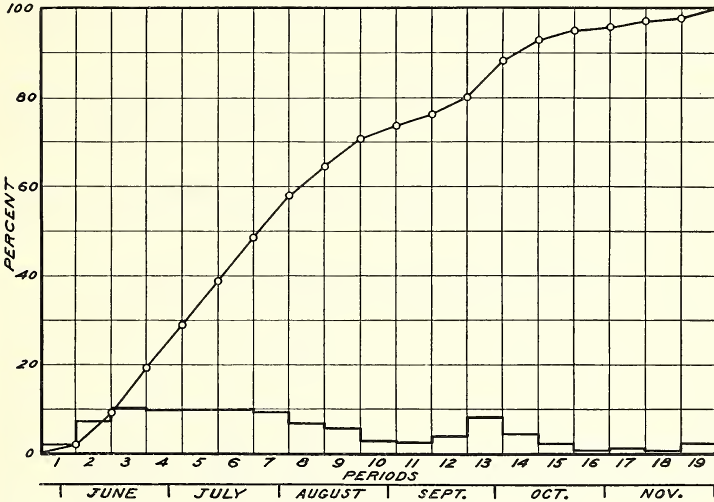

FIGURE 7.—Average cumulative per cent curve of the catch per 10-day period, from 1923 to 1930, inclusive. Histogram at base shows the percentage increments for each period

almost constant at about 10 per cent of the seasonal catch. Therefore, regulations prohibiting fishing during any portion of these periods would curtail the catch more than a proportional cut in time during any other part of the season.

During the late summer and early fall, the runs of herring have proven to be erratic, varying widely from year to year from the norm established over the period of eight years for which data are available. (Table 8.) The autumn run, which is evidently a normal condition in the fishery, was unusually abundant in 1930, being one of the chief factors in the increase in total production of 1930 over 1929. In 1929 the fall run did not appear, even though both years depended almost entirely on the same year class. This would indicate that the magnitude of the autumn run depends to a very large extent on some factor or factors other than the abundance of herring.

ANNUAL VARIATIONS IN WEIGHT OF THE INDIVIDUAL HERRING

In addition to the availability of the fish, another factor that influences the yield of the fishery is the variation in the average weight of the fish caught each season, since a smaller number of older fish may yield the same poundage as will a larger number of younger ones. If the relative abundance of the age classes were to remain constant, this factor would not need to be taken into consideration, because as each annual age increment would have approximately the same numerical strength a uniform distribution of age and size classes would be maintained from year to year from which the fishery would draw its supply. If such were the case, the average weight of the fish taken would approach a norm. However, the presence of dominant year classes causes the average size and weight to fluctuate to a marked degree, as shown by Table 9.

This table shows clearly the effect produced by the growth of dominant year classes. Thus in 1928, when the 1926 year class first entered the catch, the number of fish taken exceeded the average, but owing to their small size the catch was below normal. In 1930, after two years of growth, the size of the catch exceeded its mean more than did the number of fish.

It is thus plain that the increase in weight of the individual fish, especially during the earlier part of their existence, aids in minimizing the effects of fishing and of natural mortality.

Table 9.—*Showing the annual changes in the average weight of individual herring from 1924 to 1930, inclusive, and comparing the total catch with the number of fish*

Year	Average[1] weight of fish (grams)	Total catch[2]		Number of fish caught	
		Actual (pounds)	As per cent of average	Actual	As per cent of average
1924	86.86	17,130,000	102.4	89,454,000	129.6
1925	106.98	23,260,000	138.5	98,621,000	142.9
1926	147.03	9,239,000	55.2	28,502,000	41.3
1927	130.02	7,406,000	44.3	25,837,000	37.4
1928	92.28	15,076,000	90.1	74,104,000	107.4
1929	113.18	13,673,000	81.8	54,797,000	79.4
1930	126.97	31,288,000	187.1	111,774,000	162.0
Average	109.92	16,725,000	100.0	69,013,000	100.0

[1] Computed by weighting the per cent of fish at each length (smoothed twice by 3's) by the weight at that length from the formula $W=\frac{L^{3.18}}{K}$ (Rounsefell, 1930).

[2] Includes the Evans Island, southern Knight Island, and Montague Island areas.

SIZE AND AGE COMPOSITION OF THE CATCH

The presence of dominant year classes has been the largest factor in causing the fluctuations in abundance which have taken place. (Rounsefell, 1930.) Since this last report additional data, covering 1928, 1929, and 1930 have been secured. These body length measurements were taken from samples caught in the vicinity of Latouche (including the Evans Island area, Montague Island, and southern Knight Island) during June and July, and are fairly representative of the entire Prince William Sound district since 90 per cent of the total catch is taken in the area included, and 50 per cent of the total seasonal catch is taken during these months. Lacking definite evidence of racial differences these data may be used to represent the fishery of the entire district, with the possible exception of the Main Bay area, in which the age

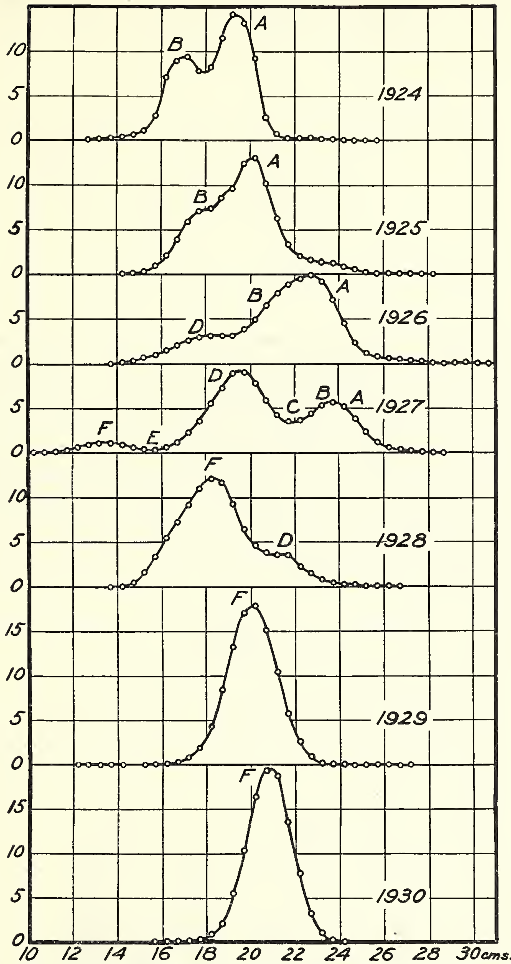

FIGURE 8.—Body length frequencies from the Evans Island, southern Knight Island, and Montague Island areas, for June and July, shown as percentages of each distribution (smoothed twice by threes)

and size distributions from Eshamy and McClure Bays differ considerably from those of the area under consideration (Rounsefell, 1930, pp. 299–301). However, the age distributions from four localities for 1929, given in Table 10, show a close agreement, justifying our disregard of possible racial differences in studying dominant year classes in these areas.

TABLE 10.—*Age distributions from four different localities in Prince William Sound for 1929*

Age	MacLeod Harbor		Evans Island Area		Southern Knight Island area		Port Chalmers	
	Actual	Percentage	Actual	Percentage	Actual	Percentage	Actual	Percentage
3	12	3.3	15	3.2	6	2.8	3	3
4	342	93.4	434	93.1	197	92.9	94	94
5	8	2.2	7	1.5	7	3.3	2	2
6	3	.8	7	1.5	2	.9	1	1
7	1	.3	3	.6				

The body lengths used in this analysis of size fluctuations were measured to the nearest millimeter. (Rounsefell, 1930, p. 239.) The lengths were grouped in 5-millimeter categories, and then smoothed twice by threes in order to remove minor modes due to chance sampling. These length distributions (fig. 8) show the progression from year to year of four distinct modes through the catch. The two modes (*A* and *B*), present in 1924, are plainly discernible in 1925, but in 1926 and 1927 they have become fused into a common mode, due, probably, to a decreasing difference in growth rate; the small mode (*D*) which first appears in 1926 may be traced through 1927 and 1928. The most prominent mode (*F*) appears in 1927 and advances through 1928, 1929, and 1930. During these two latter years this mode dominates the field, there being no minor modes. The troughs at *C* and *E* are best explained in the following paragraphs.

TABLE 11.—*Percentage length frequencies for June and July from the vicinity of Latouche smoothed twice by threes*

Body lengths (millimeters)	Percentage							Average percentage
	1924	1925	1926	1927	1928	1929	1930	
90–94				0.01				
95–99				.03				
100–104				.04				
105–109				.05				
110–114				.11				0.02
115–119				.32				.05
120–124				.61		0.01		.09
125–129	0.03			.92		.01		.14
130–134	.16			1.09		.02		.18
135–139	.32		0.02	1.09	0.02	.01		.21
140–144	.46	0.02	.10	.93	.11	.01		.23
145–149	.66	.19	.27	.59	.56			.32
150–154	1.15	.36	.58	.38	1.64	.01		.59
155–159	2.81	1.00	.97	.30	3.43	.05	0.01	1.22
160–164	7.05	2.06	1.50	.64	5.49	.14	.04	2.41
165–169	8.99	3.96	2.03	1.21	7.41	.36	.10	3.43
170–174	9.46	5.87	2.60	2.29	9.23	.79	.21	4.34
175–179	7.84	7.03	3.02	3.62	11.02	1.95	.40	4.97
180–184	8.22	7.46	3.16	5.50	12.19	4.42	.95	5.98
185–189	11.55	8.51	3.21	7.36	11.63	8.48	2.15	7.54
190–194	14.20	9.67	3.22	8.86	9.29	13.34	5.46	9.13
195–199	13.13	12.46	3.85	9.03	6.49	17.04	10.34	10.32
200–204	9.21	13.07	4.98	7.84	4.63	17.86	16.37	10.55
205–209	2.58	10.20	6.60	5.93	3.94	15.18	19.38	9.10
210–214	.69	6.30	7.91	4.26	3.58	10.48	18.66	7.40
215–219	.37	3.41	8.92	3.51	3.11	5.77	13.57	5.51
220–224	.35	2.05	9.57	3.68	2.31	2.56	7.84	4.04

TABLE 11.—*Percentage length frequencies for June and July from the vicinity of Latouche smoothed twice by threes*—Continued

Body lengths (millimeters)	Percentage							Average percentage
	1924	1925	1926	1927	1928	1929	1930	
225–229	0.29	1.65	9.99	4.45	1.54	0.95	3.24	3.15
230–234	.21	1.43	9.21	5.30	.87	.33	1.02	2.62
235–239	.14	1.26	7.24	5.66	.51	.12	.21	2.16
240–244	.06	.91	4.52	5.17	.33	.04	.04	1.58
245–249	.03	.55	2.39	3.86	.27	.01		1.01
250–254	.01	.23	1.24	2.32	.18	.01		.57
255–259	.01	.15	.83	1.23	.14	.01		.34
260–264		.15	.67	.66	.09	.02		.23
265–269		.11	.52	.45	.04	.01		.16
270–274		.06	.39	.32		.01		.11
275–279		.01	.29	.21				.07
280–284		.01	.16	.11				.04
285–289			.06	.04				.01
290–294			.11					.02
295–299			.22					.05
300–304			.33					.05
305–309			.22					.05
310–314			.11					.02
Number of specimens	2,000	6,889	1,041	785	615	1,585	782	13,697
Number of samples	10	70	17	14	14	20	14	159

By plotting the deviations of the curves for each year from the average curve for the seven years, the relative lack of certain size groups becomes apparent, not only as compared to the other sizes for the same year, but also as compared to the average of the same sizes over the entire period of seven years. (Fig. 9.) The top curve shows the average for the seven years, computed by summing the weighted (percentage) frequencies of each of the seven annual curves, and dividing by seven to obtain the mean at each ordinate. From this standard curve the deviations of each of the seven years were plotted, those above the line (solid black) indicating a frequency greater than the average, those below the line (diagonally barred) indicating a frequency less than average. Here we find the same condition of certain abundant size-groups progressing through the catch from year to year as is shown by Figure 8. Figure 9 also shows, however, that certain size-classes are present in less than normal proportions. (*C* and *E*, fig. 8.) Those size-classes which are not present in normal proportions, likewise progress through the catch from year to year.

Evidence that the progression of size-modes is due to growth from year to year, is furnished by the age analysis. Figure 10 shows the age frequency distributions on a percentage basis. Although there may be some error in the age readings, they are of great value in interpreting the significance of the size-modes, and the consistency of the results obtained by the two methods is further proof of their validity.

TABLE 12.—*Percentage age distributions from the vicinity of Latouche, Prince William Sound* [1]

Age	1925		1926		1927		1928		1929		1930	
	Actual	Percentage	Actual	Percentage	Actual	Percentage	Actual	Percentage	Actual	Percentage	Actual	Percentage
2					25	4.0						
3	13	7.9	35	9.0	38	6.1	330	78.2	36	3.1	7	0.9
4	42	25.4	137	35.4	343	55.2	39	9.2	1,067	93.3	82	10.8
5	59	35.8	82	21.1	69	11.1	37	8.8	24	2.1	662	87.5
6	11	6.7	120	31.0	43	6.9	15	3.6	13	1.1	5	.7
7	11	6.7	3	.8	82	13.2	1	.2	4	.4	1	.1
8	6	3.6	3	.8	2	.3						
9	4	2.4	1	.3	9	1.4						
10	9	5.4	1	.3	5	.8						
11	10	6.1	3	.8	4	.6						
12			2	.5	1	.2						
Number	165		387		621		422		1,144		757	

[1] Inclusive of Evans Island, southern Knight Island, and Montague Island during the months of June and July.

The existence and the progression through the catch of dominant year classes is more clearly shown by the age distributions than by those of length. The 1921 year class (cross hatched) is dominant over that of 1922 (solid black) for the three years in which it enters the catch. The 1923 year class (vertically barred) is also slightly dominant over that of 1922. The 1924 year class (stippled) appears to be much more numerous than those of 1923 and 1922, but is dwarfed in 1928 by the overwhelming

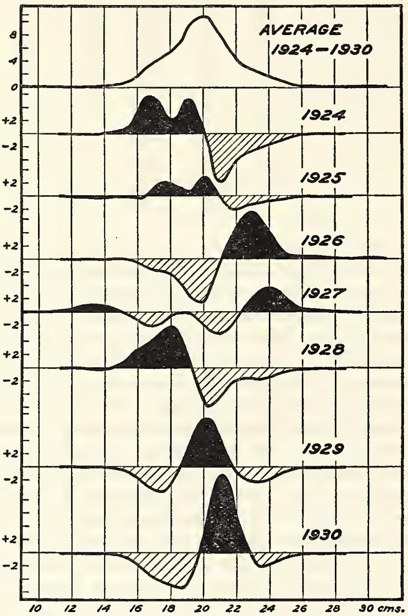

FIGURE 9.—Showing the percentage deviations of each of the annual length-frequency curves (fig. 8) from the 7-year average

abundance of the 1926 year class (horizontally barred), which maintains its dominant position through 1930.

The 3-year-olds of 1925 and the 3-year-olds of 1926 make a sharp rise in percentage taken between their third and fourth years and the same would have been true of the 3-year-olds of 1927, but for the great abundance of the 1926 year class. These fish do not enter the catch in true proportion to their actual abundance as 3-year-olds partly on account of differential schooling and partly on account of selection of sizes by the fishing gear. The 2-year-olds of 1927 made a sharp rise in the percentage taken between their second and third years. In fact, this year class is the only one which entered the catch as 2-year-olds. This difference in their availability to the fishermen as compared to the other year classes may have been caused by the unusual abundance of the 1926 year class inducing these young fish to school with the older and more

mature fish, or to the unusually high rate of growth causing the larger fish of this year class to attain a size suitable for schooling with the older fish at an earlier age. That the 1926 year class actually did grow at a faster than normal rate is shown by comparing the positions (fig. 8) of mode F in 1928 with mode B in 1924 and mode F in 1929 with mode D in 1927.

The effect of dominant year classes on the catch is expressed in the following quotation (Rounsefell, 1930):

The presence of dominant age groups may have a far-reaching effect; at times a race may be exceedingly abundant and at other times exceedingly scarce, for there may be periods of several

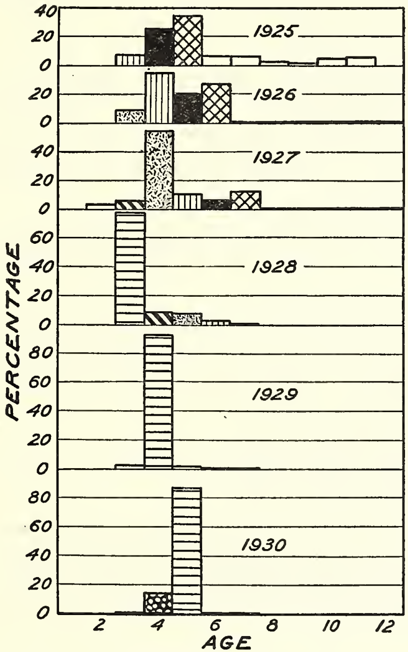

FIGURE 10.—Age frequencies from Evans Island, southern Knight Island, and Montague Island areas for June and July, shown as percentages of each distribution

years between dominant year classes, the population becoming much reduced before another dominant year class appears in the catch. The appearance of such a year class may cause excessive abundance for a time. When a very dominant year class first enters the commercial catch its members will be small, lowering the average size of the fish in the whole catch. Later, as the fish of this year class grow older, the average size of the fish in the commercial catch will be gradually raised, until another dominant year class appears and temporarily lowers it.

The fluctuations in the catch caused by these dominant year classes are of great importance to the fishery. During the intervals when no abundant year classes of

young fish are present, the fishery must be supported by a reserve of the older age groups. Depletion of these older age groups by a too intensive fishery has caused the variations in the yield which have characterized the fishery during the past few years. Unless protection is adequate to insure a sufficient quantity of older age groups at all times the fishery can not be maintained without such undersirable fluctuations.

REGULATIONS

In 1924, acting under the authority vested in the Secretary of Commerce by the White law which was enacted by Congress in that year, the Department of Commerce promulgated regulations for the herring fishery. Prior to that time, no restrictions had been imposed. The regulations are as follows:

Under date of June 21, 1924:

1. Fishing for herring is prohibited during the period from January 1 to June 24, both dates inclusive, and from November 1 to December 31, both dates inclusive, of each calendar year, except for bait or for local food purposes.
2. Gill nets used in catching herring shall not be of smaller mesh than 3 inches, stretched measure.
3. No one shall place, or cause to be placed, across the entrance of any lagoon or bay any net or other device which will prevent the free passage at all times of herring in and out of said lagoon or bay.

Under date of October 13, 1924:

Commercial fishing for herring in the waters of the Prince William Sound area will be permitted with gill nets of mesh not smaller than 3 inches, stretched measure, from November 1 to November 30, 1924, inclusive.

Under date of October 25, 1924:

The regulation of October 13, 1924, permitting commercial fishing for herring in the waters of the Prince William Sound area with gill nets of mesh not smaller than 3 inches, stretched measure, from November 1 to November 30, 1924, inclusive, is hereby modified to permit the use of gill nets of mesh not smaller than 2¼ inches, stretched measure, in the Prince William Sound area from November 1 to November 30, 1924.

Under date of November 24, 1924:

Commercial fishing for herring with purse seines in the waters of the Prince William Sound area will be permitted through December 15, 1924.

Under date of December 2, 1924:

1. Commercial fishing for herring is prohibited during the period from January 1 to June 24, both dates inclusive, and from November 1 to December 31, both dates inclusive, of each calendar year.
2. The closed seasons herein specified for herring fishing shall not apply to any boat taking not to exceed 60 barrels of herring in any calendar week in waters open to fishing.
3. Commercial fishing for herring is prohibited in all waters closed throughout the year to salmon fishing.
4. Gill nets used in catching herring shall not be of smaller mesh than 2¼ inches, stretched measure.

Under date of January 28, 1925:

Regulation No. 1 is amended to read as follows: Commercial fishing for herring is prohibited during the period from January 1 to June 24, both dates inclusive, and from November 16 to December 31, both dates inclusive, of each calendar year.

Regulation No. 3 is amended to read as follows: In the period from June 1 to October 1, both dates inclusive, commercial fishing for herring is prohibited in all waters closed throughout the year to salmon fishing.

Under date of December 5, 1925:

3. During the period from June 25 to October 1, both dates inclusive, commercial fishing for herring is prohibited in all waters closed throughout the year to salmon fishing.

Under date of July 1, 1926:

Regulation No. 2 is amended to read as follows: The closed seasons herein specified for commercial herring fishing shall not apply to the taking of herring for bait purposes in waters otherwise open to fishing.

Under date of December 22, 1926:

1. Commercial fishing for herring is prohibited during the period from January 1 to June 9, both dates inclusive, and from November 1 to December 31, both dates inclusive, of each calendar year.

2. The closed seasons herein specified shall not apply to the taking of herring for bait purposes in waters otherwise open to fishing.

3. Commercial fishing for herring, except for bait purposes, is prohibited from 6 o'clock postmeridan of Saturday of each week until 6 o'clock antemeridian of the Monday following.

Under date of July 26, 1927:

Regulation No. 1 is amended so as to prohibit commercial fishing for herring from October 15 to December 31, 1927, both dates inclusive.

Regulation No. 3 is amended so as to permit commercial fishing for herring from 6 o'clock postmeridian of Saturday of each week until 6 o'clock antemeridian of the Monday following.

Under date of October 11, 1927:

Regulation No. 1 is further amended so as to permit commercial fishing for herring with purse seines from October 15 to November 5, 1927, both dates inclusive, and with gill nets of not less than 2½ inches stretched measure between knots from October 15 to December 15, 1927, both dates inclusive.

Under date of December 12, 1927:

1. Commercial fishing for herring is prohibited during the period from January 1 to June 26, both dates inclusive, and from November 1 to December 31, both dates inclusive, except that gill nets of not less than 2½ inches stretched measure between knots may be used from November 1 to December 15, both dates inclusive.

4. Gill nets used in catching herring shall not be of smaller mesh than 2¼ inches stretched measure.

Under date of April 16, 1928:

Regulation No. 1 is amended to read as follows: Commercial fishing for herring is prohibited during the period from January 1 to June 15, both dates inclusive, and from November 1 to December 31, both dates inclusive, except that gill nets of not less than 2½ inches stretched measure between knots may be used from November 1 to December 15, both dates inclusive.

Under date of October 31, 1928:

Regulation No. 1 is amended to read as follows: Commercial fishing for herring is prohibited during the period from January 1 to June 15, both dates inclusive, and from November 16 to December 31, both dates inclusive, except that gill nets of not less than 2½ inches stretched measure between knots may be used from November 16 to December 15, both dates inclusive.

Under date of December 18, 1928:

1. Commercial fishing for herring, except for bait purposes, is prohibited from January 1 to June 30, both dates inclusive, and from November 16 to December 31, both dates inclusive, except that gill nets with mesh of not less than 2½ inches stretched measure between knots may be used from November 16 to December 15, both dates inclusive.

2. During the period from July 1 to October 1, both dates inclusive, commercial fishing for herring, including bait fishing, is prohibited in all waters closed throughout the year to salmon fishing.

4. Commercial fishing for herring, including bait fishing, by means of any trap is prohibited.

5. Commercial fishing for herring, including bait fishing, by means of any purse seine more than 1,400 meshes in depth, more than 180 fathoms in length, or of mesh less than 1½ inches stretched measure between knots is prohibited.

CATCH STATISTICS

The total production figures have been derived from the following sources: (1) Sworn annual reports, which the Bureau of Fisheries has required of every operator since 1904. (2) Daily catch records kept on books issued to the companies by the Bureau of Fisheries and filled in by the operators each time a load of fish is delivered to the plant. (3) Field notes. (4) Company records. Most of these records do not give the poundage taken (except in the case of halibut bait), but give the amounts of the various products which were prepared. In analyzing the statistics, it was necessary for purposes of comparison, that all amounts be put on a common basis, the unit selected being the pound of raw herring as delivered to the plant. (Rounsefell, 1930, pp. 303–305.)

The installation in 1930 of a 10-ton reduction plant in Evans Bay similar to those used in southeastern Alaska, and more efficient than the smaller type hitherto used in Prince William Sound, necessitated the use of the same conversion factors as were used in southeastern Alaska for this one plant; that is, 6.5 pounds of raw fish per pound of meal and 50 pounds of fish per gallon of oil. As a check on these figures, it was found that the actual weight, computed at 250 pounds to the barrel (the unit of measure which is used in buying the fish), was 21,000,000 pounds; the estimated weight (using the above-noted conversion factors for the meal and oil) was 21,631,706 pounds. The discrepancy between these figures may be partially accounted for by taking into consideration the fact that the unit of measure (a barrel containing 31.5 gallons) may hold more or less than its estimated 250 pounds, depending on the size and condition of the fish. Also the conversion factors are influenced by the fatness of the fish, a condition which can not be closely estimated since it varies greatly within the season as well as between seasons.

The converted products are listed in Table 13, and plotted in Figure 11. This figure shows a rapid increase in the catch from 1918 until 1922, a steady decline from then until 1927 (except for a minor rise in 1925), followed by a rise continuing through 1930. However, the total catch figures are of no significance as far as giving an index to the actual abundance of fish is concerned, unless some measures of the intensity of the fishery and of the changes in the size or age composition of the herring populations are considered.

TABLE 13.—*Pounds of raw herring caught in Prince William Sound, 1917 to 1930*

Year	Used for reduction	Pickled	Used for bait	Canned	Total
1917		229,458	270,482		499,940
1918		7,230,900	691,800		7,922,700
1919		7,104,848	411,126	2,565,300	10,081,274
1920	10,355,700	9,185,591	20,000	375	19,561,666
1921	1,914,000	16,709,239	12,000		18,635,239
1922	6,784,757	37,145,225	524,600		44,454,582
1923	13,854,488	19,730,903	1,451,759		35,037,150
1924	12,446,879	4,216,023	1,387,750		18,050,652
1925	17,117,594	10,073,336	14,250		27,205,180
1926	7,479,322	2,586,779	712,550		10,778,651
1927	4,771,314	4,379,418	341,750		9,492,482
1928	13,863,218	933,427	340,000		15,136,645
1929	13,470,718	157,188	45,400		13,673,306
1930	29,486,145	1,988,994	139,100		31,614,239
Total	131,544,135	121,671,329	6,362,567	2,565,675	262,143,706

These factors are shown in Figure 12 giving the total catch, the number of vessels engaged in the fishery (weighted by the length of time spent in Prince William Sound and the relative productivity of that time, estimated from the catch per 10-day period), the portion of the catch used for pickling, and the reduction plant capacities, plotted on a logarithmic scale to show comparative rates of change. Before entering

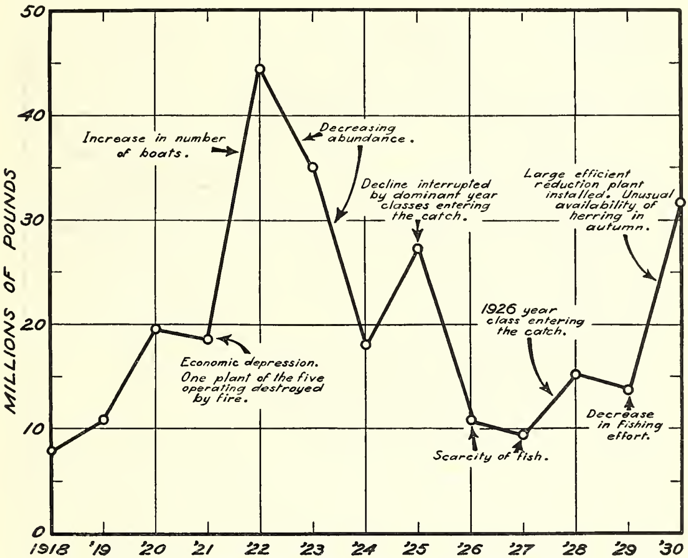

FIGURE 11.—Self-explanatory graph of the changes in the total catch and their causes

further discussion, however, the regulations governing the fishery should first be considered.

Figure 13 shows the opening and closing dates which have been in force in Prince William Sound. The regulations governing the opening dates of the seasons are the only ones which have measurably affected the catch, the closing dates having had little influence. (Fig. 7.) The effect which the shortening of the season has had on the total catch is difficult to measure because no accurate records were kept of the dates on which herring were taken prior to 1923, but the conclusions from the available data are given in Table 14.

TABLE 14.—*Effect of closed seasons on the catch in Prince William Sound*

Year	1924 [1]	1925	1926	1927	1928	1929	1930
Per cent reduction of catch by closed seasons [2]	0.0	22.9	22.9	8.9	11.8	27.7	27.7

[1] Closed seasons were not effective until 1925.
[2] Computed from catch per boat per 10-day period.

For those years which the data cover, the fact that many of the same companies and boats which operated in Prince William Sound also operated in the Kodiak-Afognak district, in Cook Inlet, and (in 1928) at Unalaska influences the proportions of fish taken from this area before, compared with that taken after, the date upon which fishing is permitted in these other localities. The season has usually opened

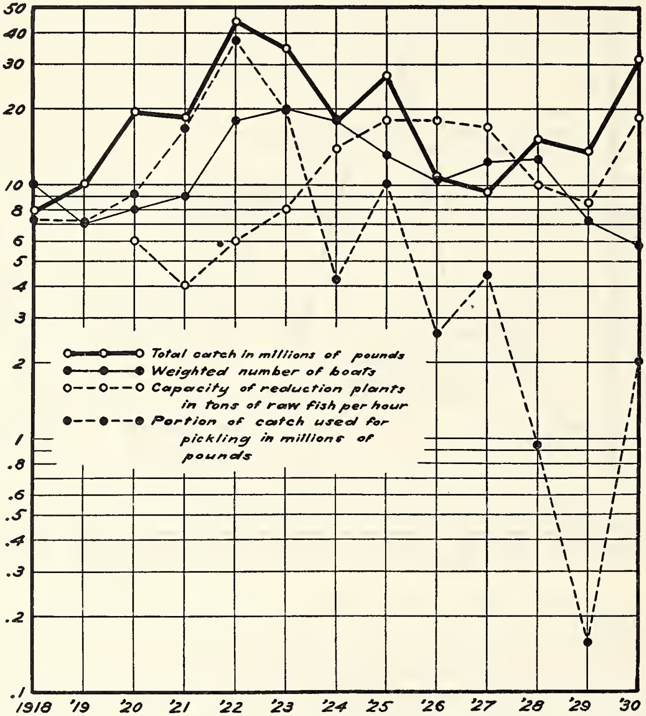

FIGURE 12.—The catch of raw herring, the weighted number of boats, the capacity of the reduction plants, and the portion of the catch used for pickling, plotted on a logarithmic scale to show the comparative rates of change

about three weeks earlier in Prince William Sound than in the aforementioned districts. These other areas usually have produced larger fish than has Prince William Sound, so that while good runs of herring occur there, the operations in Prince William Sound are curtailed in favor of these more profitable fisheries.

No weighting to allow for tonnages of the boats operated has been made. Table 15 shows the number of boats used and the average net tonnages of those vessels of which the capacities are known. Although there has been an increase in tonnage per boat since 1918, the changes since 1922 have been small and erratic. The efficiency

of the boats, and the effectiveness of their gear have also been disregarded in this analysis, because no measure of these is available. For instance, the introduction of the power seine roller was a great advancement over the former method of pulling

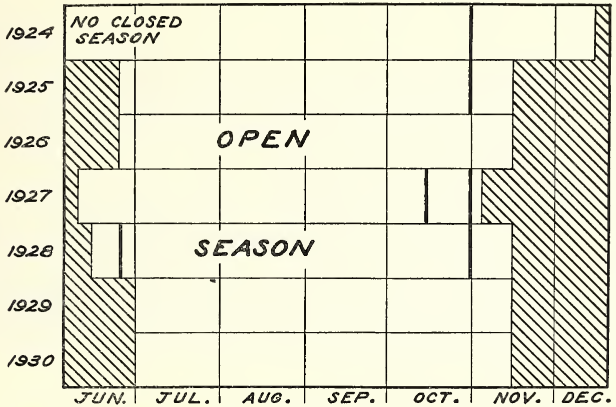

FIGURE 13.—Legal fishing seasons in Prince William Sound. The first closed period became effective in December, 1924. Unshaded portions indicate open seasons. The heavy vertical lines in 1924, 1925, 1927, and 1928 indicate opening and closing dates changed, before becoming effective, by supplementary regulations

seines by hand, but we have no records of when it was first introduced, and no method of determining the effect which it has had on the catch.

TABLE 15.—*Purse seine fleet of Prince William Sound*

Year	Number of boats	Number with tonnages known		Average net tonnage	Year	Number of boats	Number with tonnages known		Average net tonnage
		Actual	Per cent				Actual	Per cent	
1918	10	8	80.0	17.25	1925	26	22	84.6	23.73
1919	7	6	85.7	16.50	1926	21	20	95.2	22.65
1920	8	5	62.5	16.60	1927	21	20	95.2	25.20
1921	9	7	77.8	18.71	1928	26	25	96.2	25.60
1922	18	15	83.3	21.93	1929	10	10	100.0	21.70
1923	20	20	100.0	19.25	1930	8	7	87.5	23.14
1924	25	17	68.0	21.53					

The fishery of Prince William Sound was developed primarily for the pickled product. The fish were superior in quality to those taken in southeastern Alaska, and a market was readily found for them (p. 264). The first reduction units (Table 1) were introduced chiefly to utilize the waste which accompanies the curing process. Large fish predominated in the catch, and the mild-curing of herring was a thriving business.

The curing industry requires a supply of large fish, which must be brought to the saltery in good condition. The fishermen, therefore, made special efforts to take only the larger fish, usually disregarding the schools of smaller individuals. Their

seasonal catch, consequently, was smaller than it would have been had the plants been able to utilize any fish which they could have taken, and at the same time the younger age classes were afforded protection. Furthermore, the curing of herring requires much hand labor, and the daily capacity of a saltery was limited to the amount of fresh fish which could be handled. Much fishing time was lost impounding "feedy" loads of herring to allow them time to cleanse their intestinal tracts of food material (for description of impounding, see Rounsefell, 1930, pp. 231–232).

The introduction of the reduction units largely removed these limitations placed on the amount and size of the fish which could be utilized by the plants. The change from a fishery for salting to one for reduction has been gradual, and culminated in 1928 when the relative proportions of pickling fish in the catch became unusually low. This was due partly to the tremendous abundance of the 1926 year class which was then entering the catch as 3-year-olds and partly to earlier overfishing, which had caused the practical disappearance of the older age groups. The size of these 3-year-olds made them unsuitable for packing, but their abundance was sufficient to maintain a fishery for reduction products.

The change of interest from pickled herring to fish oil and meal has caused some change in the conduct of the fishery. Precious fishing time is no longer wasted while small loads of "feedy" fish are impounded. Now impounding is resorted to only at times of unusual abundance so as to keep the reduction plants busy during a period of scarcity or of weather too stormy for fishing. No size limit for the fish to be taken is observed, and fishermen seldom spend much time searching for schools of large herring. In operating a reduction plant without salting, the machinery can be kept operating constantly without having to wait upon the limitations that are necessarily imposed when all of the larger fish must be sorted out for pickling.[2]

Referring again to Figure 12 we find the curve showing the number of boats corrected to allow for the factors of regulations restricting the fishing season and time spent by the boats during the season at grounds other than Prince William Sound. From 1918, when the exploitation of this region began on a large scale, until 1922, the total catch and the weighted number of boats increased in about relative proportions. From 1922 until 1928 there was a decrease in total catch in proportion to the weighted number of boats fishing (except in 1925). During 1929 and 1930, however, a decreased number of boats caught an increased poundage. Apparently, then, although there was a decline in abundance beginning in 1923 and continuing through 1927, the 1926 year class was sufficiently abundant to cause the fishery to approach the abundance of earlier years. Since the fishery is drawing almost entirely from this year class, however, a decline to former low levels of abundance may be expected shortly unless the intensity of the fishery is reduced, or a new abundant year class appears.

CONCLUSIONS

1. The fishery is highly localized. Over a period of 8 years, 51 per cent of the catch was taken in the waters adjacent to Evans Island, 26 per cent in Macleod Harbor and Hanning Bay on Montague Island, 14 per cent in a few small bays on the southern end of Knight Island, and 7 per cent in the small area from McClure Bay to Eshamy Bay (including Main Bay). The whole of the remainder of Prince William Sound produced less than 3 per cent of the catch during this period.

[2] During 1929, however, at least one of the plants operated its two boats only on alternate days, since the limited capacity of the 2-ton reduction unit would not handle all of the fish which could have been taken. Had the plant sufficient capacity, its production could have been doubled during part of the season.

FIGURE 14.—Pickled herring on the wharf at Port Benny, Evans Bay, receiving fresh brine before being shipped to Seattle. Taken in 1927

FIGURE 15.—Repairing a torn purse seine on the dock at the Crab Bay plant in Evans Bay. Taken in 1928

2. The means of the vertebral counts of each year class of herring in Prince William Sound showed a very high negative correlation, —0.85, with the temperatures during the period in which the eggs and larvæ of each year class were spawned and developed, showing that the differences in the means of the vertebral counts within Prince William Sound are chiefly, if not wholly, due to environmental conditions and not to genetic differences.

3. Comparisons of the means of the vertebral count distributions of fish of the same year class from neighboring localities suggest that McClure Bay has a stock of herring independent of those caught elsewhere in Prince William Sound but can not be definitely said to differ without further data.

4. The availability of the herring schools to the fishermen varies widely during different portions of the fishing season, as shown by the catch per boat per 10-day period, being highest during July, reaching a low point about September 20, rising to a second peak during the period from September 23 to October 2, and then fluctuating at a low level until the end of the season.

5. The herring normally enter the commercial catch in true proportion to their relative abundance during their fourth summer, although exceptionally rapid growth may cause the fish to enter the catch in large numbers during their third summer.

6. The great fluctuations in abundance that have occurred in Prince William Sound have been due largely to the growth and passage through the commercial catch of fish of dominant year classes.

7. In order to avoid violent fluctuations in the yield of the fishery a reserve of older age classes must be maintained.

8. The only regulations that have had a limiting effect on the fishery are those defining the fishing season.

9. In the period from 1925 to 1930, inclusive, the closed periods for fishing have probably decreased the total catch from about 9 to 28 per cent in the various years.

10. The present fishery is losing much profit by taking large quantities of young herring for reduction, that should be permitted to reach an age of 6 years and over before being caught.

RECOMMENDATIONS

FUNDAMENTAL CONSIDERATIONS

In order to prevent a recurrence of a scarcity of herring as in 1926 and 1927, or of the lack of fish of pickling size that characterized 1928, 1929, and to a large extent 1930, it will be necessary to protect the 1926 year class (now composing the bulk of the catch) until sufficient numbers of herring of another or other year classes also reach pickling size. As mentioned elsewhere the 1927 year class was poor. From the great scarcity of 3-year-olds in the 1930 age distributions it is extremely probable that the 1928 year class was a practical failure. In applying protection to this fishery one must not be mislead by the present abundance (due wholly to the 1926 year class), as year classes as abundant as that of 1926 are the exception, so that adequate protection must be given during periods of abundance if the fishery is to avoid periods of great scarcity.

The catch may be limited by restrictions on gear, fishing season, localities fished, or the size of fish taken. However, each type of regulation has its own peculiar advantages and disadvantages. Regulating the size of fish to be taken, for instance, is not very practicable in a purse seine fishery, as the gear catches all sizes

of fish that are in the school. Limitations on the length of the fishing season are often of great benefit and have the advantage of being easily enforced. The closing of certain localities is often feasible, especially if various localities are frequented by schools of herring of different sizes. Also, some localities may be better adapted to certain types of gear. Restrictions on the type or size of the unit of gear may be quite effective if it is desired to protect certain sizes of fish, or if it is feared that a shorter fishing season will merely result in the use of more gear, with a consequent loss to the operators, without a corresponding reduction in the catch.

It seems desirable in the present case to combine these methods. The season in Prince William Sound is unnecessarily long for a district in which reduction plants are operating. In southeastern Alaska the present season is only four months minus a weekly closed season of 36 hours, while in Prince William Sound the present season covers 4½ months. The question, of course, arises as to whether it would be best to shorten the present season at either end, or to impose a weekly closed season. Of the two, the weekly closed season is preferable in that it would cut off practically the same proportion of the catch each season. It would have the added advantage of allowing the saltery crews a period in which to repack the "seasticks" that had accumulated, instead of having to do this during the time fish were available for salting. A weekly closed season would therefore tend to increase the proportion of fish used for salting, allowing the companies to make a larger proportionate return on the fish caught.

The gear also needs regulation. The purse seine boats used range in size from 12 to about 40 net tons, and the purse seines from 150 to 180 fathoms in length. In this district where the distances are short and practically all of the seining is done in comparatively sheltered waters the sole advantage of a large seine boat is in its carrying capacity. The carrying capacity of these larger boats is a disadvantage, however, in so far as the most economical use of the resource is concerned, as the crushing weight of such loads renders quantities of otherwise suitable herring unfit for pickling. Also, it is these larger boats that render possible the operation of reduction plants independently of the supply of pickling fish. This criticism is not aimed at the use of herring for reduction, but at the exploitation by the reduction plants of immense quantities of small herring that in one to three years' time would be of a size suitable for salting. Since taking only large fish would tend to stabilize production, as explained above, and as the use of large boats increases the possibilities of profit from the small fish, it seems desirable to limit the size of the boats. This we believe can best be accomplished by limiting the size of the purse seine. With the shorter seine the large boats would have difficulty in securing full loads. However, this would be fairer than limiting the size of boats, as some operators might still wish to use large boats, and their use would not be objectionable when not carrying full loads.

SPECIFIC RECOMMENDATIONS

1. That commercial fishing for herring with seines, except for bait purposes, be prohibited from 12 o'clock noon on Saturday of each week until 12 o'clock noon on the Monday following.

2. That commercial fishing for herring, including bait fishing, by means of any purse seine more than 1,200 meshes in depth, more than 150 fathoms in length, or of mesh less than 1½ inches stretched measure between knots be prohibited.

3. That commercial fishing for herring, including bait fishing, by means of set and drift gill nets of mesh not less than 2½ inches stretched measure between knots be permitted until December 15 of each calendar year.

4. That the use of herring of over 10½ inches in total length, measured from the tip of the snout to the end of the tail fin, for reduction purposes be regarded as wanton waste under section 8 of the act of June 26, 1906. Any willful use or changes of gear, machinery, or handling so as to depreciate the value of herring as food shall be considered as an infringement of this regulation.

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CONTRIBUTIONS TO THE EARLY LIFE HISTORIES OF SIXTY-TWO SPECIES OF FISHES FROM LAKE ERIE AND ITS TRIBUTARY WATERS[1]

By Marie Poland Fish

CONTENTS

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INTRODUCTION

That tremendous mortality among fishes must occur is evident from the fact that the individuals of many species spawn thousands and often millions of eggs yearly without an appreciable increase in the numbers of adult fish. Undoubtedly a high percentage of destruction is normal and necessary in suppressing overproduction and providing food for other organisms. Sometimes, however, this mortality becomes abnormally large, due either to unfavorable environmental conditions or the inroads of man, and the stock is seriously depleted. It is generally believed that the greatest losses at such periods take place during the egg stage or soon after the free-swimming larva emerges; hence the need for studying early life histories is apparent.

Although much has been done on marine fishes, practically nothing beyond fragmentary notes for a few species has been available on the developmental stages of their fresh-water relatives. No one has previously considered this embryonic, larval, and postlarval community as a whole. The study of early life histories, dovetailed with an investigation of biological, physical, and chemical conditions of the environment, is necessary in order to understand problems of production, abundance, and depletion in fish fauna, to determine the causes of yearly class fluctuations and their ultimate effect upon commercial fishing, or to solve other problems of real economic importance. Such a comprehensive survey has been attempted in Lake Erie, and the present paper is one of a series which will result from that study.[2]

The first step in the fish problem had necessarily to be the identification of the young of each species in various developmental stages. Thus, the following text deals, for the most part, with descriptions of specimens taken in net hauls. Because of this manner of collection the life history series are seldom as complete as desired, but all young fish taken by the cooperative survey of Lake Erie in 1928 and 1929 are included in the distribution tables, and whatever developmental stages were found are described and figured under the various species heads.

Statistics compiled recently by the United States Bureau of Fisheries show the annual value of the Great Lakes fisheries to total nearly nine millions of dollars. In Lake Erie alone in 1927 the catch brought $1,831,284 to American fishermen. Such an industry can not be disregarded, and when it declines noticeably, the need of

[2] Preliminary reports have appeared in Vol. XIV, No. 3, and Vol. XV, No. 1, Bulletin of the Buffalo Society of Natural Sciences, and in "A Biological Survey of the Erie-Niagara System," Supplemental to the Eighteenth Annual Report, 1928, New York State Conservation Department. Further reports will be published in forthcoming Bulletins of the U. S. Bureau of Fisheries.

remedial measures or, at any rate, an understanding of contributing factors toward these losses, is urgently indicated. Because an alarming decrease has occurred during late years in the numbers of commercial fish available from Lake Erie, this survey under the direction of Dr. Charles J. Fish was inaugurated in the spring of 1928 to attempt an explanation of the causes and, if possible, to suggest methods of remedy. Pooling resources, equipment, and workers, the United States Bureau of Fisheries, the New York State Conservation Department, the Ontario Department of Game and Fisheries, the health department of the city of Buffalo, and the Buffalo Society of Natural Sciences launched upon an intensive investigation of these waters.

A steam vessel, the U. S. F. S. *Shearwater*, was used constantly throughout the spring and summer of 1928 in eastern Lake Erie to the westward boundary of New York State and to Long Point on the Canadian shore. Between June 15 and July 26 the New York State gasoline launch *Navette* made observations and collections in shallow water around the margin of the lake.

In 1929 the investigations were continued in similar manner aboard the *Shearwater*. The region surveyed, however, was increased to include the whole of Lake Erie. The State of Ohio joined forces with the previously cooperating institutions, and the waters of the lake were combed for young fish.

In 1930 no active collecting was done, but over 20,000 young fishes which had been taken by the Ohio Division of Fish and Game in the previous year were examined, identified, charted, and described in an attempt to locate formerly undescribed young and further stages of fishes already recorded by the cooperative survey.

COLLECTION OF MATERIAL

Petersen young-fish trawls of quarter-inch square mesh at all depths, silk Helgoland trawls on the bottom, and meter nets at the surface and deeper levels were used during 1928 for the collection of young fish material. The only collecting gear used in the following year were meter nets and occasional dip nets. At each station investigated a typical plankton net of No. 0 and No. 2 silk with a ring 1 meter in diameter was towed for 5 minutes at the surface, and another simultaneously at about 1 meter above the bottom. The samples were preserved in weak formalin at once and examined later in the laboratory. Because of the greater area covered by the survey in 1929 and the large number of observations necessary, the towing of Petersen and Helgoland trawls was omitted, but the use of these specially constructed young-fish nets is strongly recommended for the capture of such material.

Additional specimens studied were collected by members of the staff and reared at the Buffalo Museum of Science. Others were kindly loaned by various State and Federal hatcheries.

LABORATORY TECHNIQUE

When the plankton bottles arrived in the laboratory they were carefully examined, and all young fish and eggs removed. Specimens were preserved in 2 per cent formalin in distilled water, thus preparing them for later staining and clearing if desired.

There is only one character remaining comparatively constant throughout the life of the individual, and that is the vertebral count. Thus in the earliest stages, before the fin rays and other diagnostic characters of the adult are distinguishable, the number of vertebræ is the most valuable hint of identification, and it is with this count that much of the work must be done. There are certain peculiarities for each

species, especially shape and pigment marking, which make them easily distinguished subsequently, but the first attempt at identification of field collections is possible only by counting the vertebræ. This information, together with knowledge of the adult fish fauna of the locality, permits us to narrow down the possibilities and very often to detect the species immediately. Unfortunately, the importance of the vertebral count has only recently been recognized, and thus the older descriptions of fish do not contain it. Wherever possible during the work, we have made these counts of the adults as well as the young. In some small specimens strong light is sufficient to reveal the spinal column, but usually it is necessary to stain and clear, and in larger fishes to bisect. The limited time of the survey prevented extensive staining, and when the spinal column was not readily shown, myomere counts were made which, although not identical, correspond to the vertebral count sufficiently and are constant enough for the usual requirements.

No detailed rules can be laid down for the technique of staining all young fishes, for the variation in size, permeability, and general reaction seems to make each species and often each specimen a problem in itself. Most processes are long and require considerable watching, but painstaking care and patience will surely produce results worth the effort. (See fig. 121 and other photographs of stained and cleared specimens in the following text.) The several methods used with success by the author are briefly outlined below.

VERY SMALL SPECIMENS WITH CARTILAGINOUS SKELETONS

Approved stain.—"New Methylene Blue" (Chromatine Blue Violet), National Aniline & Chemical Co., Buffalo, N. Y.

Preparation of staining solution.—One gram of dry methylene blue dissolved in 400 cubic centimeters of 70 per cent alcohol, acidulated with a few drops of 10 per cent hydrochloric acid. (Do not keep stock solution acidulated but add acid immediately before use.)

Wash formalin-preserved specimens in distilled water and run gradually up to 70 per cent alcohol, then place in staining solution and examine frequently until stained a deep midnight blue. The time varies from a few hours to more than a week. Usually at least 3 or 4 days are necessary. Wash in successive changes of acidulated 70 per cent alcohol until the color ceases to wash out of the tissues. Place in 95 per cent alcohol for 1 to 2 hours, and finally into oil of cloves. Peppermint oil, xylol, and pyridin can be used successfully, but oil of cloves is preferred inasmuch as its clearing powers are very effective, and it can be used directly from 95 per cent alcohol.

LARGE SPECIMENS WITH BONY SKELETONS

Approved stain.—Alizarine sodium sulphonate.

Preparation of staining solution.—Aqueous solution for Method I: Saturated solution of alizarine in distilled water. Alcoholic solution for Method II: Saturated solution of alizarine in 70 per cent alcohol.

Method I (most rapid but apt to be less effective): Soak formalin preserved specimens in distilled water for at least 1 hour. Stain slightly with aqueous alizarine solution (depth of stain must be determined by experiment). Avoid overstaining. Dehydrate, and clear in xylol from absolute alcohol.

Method II: Soak formalin-preserved specimens in distilled water for at least 1 hour, and in 35 per cent alcohol for from 1 to 2 hours. Place for half an hour in 70 per cent alcohol made alkaline by adding a drop or two of the following alkaline alcohol solution: 70 cubic centimeters absolute alcohol, 30 cubic centimeters distilled water, 1 cubic centimeter molecular solution of sodium bicarbonate. Stain with alcoholic alizarine solution diluted with an equal quantity of 70 per cent alcohol, to which is added one or more drops of alkaline alcohol solution until the color is a faint brown. Staining may require from 1 hour to a day or longer, depending upon the size and permeability of the specimen. Place in 70 per cent alcohol until color is washed out of flesh and left only in bones. Run slowly up to absolute alcohol. Clear in oil of cloves, oil of wintergreen, or xylol.

Method III (most effective for transparency of vertebral column): In order to make the stained skeleton distinct the use of potassium hydroxide is highly successful. This transparency method was recommended by Beale as early as 1853, and by Schultze in 1897. The techinque of Schultze has been applied widely since by students of human embryology, (e. g., von Halvar Lundvall, (1905); Eben C. Hill, (1906); Franklin P. Mall, (1906).) More recently, excellent results have been obtained in the study of deep-sea fishes by Dr. William Beebe and Miss Gloria Hollister.

The following modification of the Schultze and Lundvall methods has been used by the author in the present problem: Treat formalin-preserved specimens with 2 per cent potassium hydroxide to which has been added a few drops of alizarine solution (about 1 to 1,000) until bones are stained. The time varies from a few hours to a week, but usually one-half to one day is sufficient. Place in 1 per cent potassium hydroxide until color washes out of soft tissues. Place in glycerine and 1 per cent potassium hydroxide (1 to 5) for 4 to 48 hours, or until tissues are quite clear. Transfer to higher percentages of glycerin at intervals of one day until perfectly transparent.

It is urgent that distilled water be used in all solutions, including the formalin for hardening, since slight impurities may interfere with complete clearing.

Hill (1906) was successful in rendering difficult embryological material transparent by using equal parts of 1 per cent potassium hydroxide and 50 per cent ammonium hydroxide for 5 to 72 hours, then 20 per cent glycerin for 48 or more hours, and ascending percentages of glycerin at intervals of 2 or 3 days.

For staining Hill advocated Doctor Bardeen's alum-cochineal method. Specimens without previous fixing in formalin, are placed in 95 per cent alcohol until shriveled, then stained for 24 hours in alumcochineal and cleared in 1 per cent potassium hydrate.

ADDITIONAL METHODS OF STUDY

The perfect way to identify a young fish with the adult is, of course, to secure a ripe female and male, artificially fertilize the eggs, and study the resultant developmental stages in the laboratory. The difficulty, however, of keeping most larval specimens alive and healthy in the ordinary laboratory for long after the yolk sacs are absorbed and the fish are actively feeding is great. Even when successful the artificially reared specimens are apt to be emaciated and their growth retarded. We can not duplicate exactly their normal conditions of life, and thus the chief source of young-fish material must be the lake itself. By extensive collecting over a period of

time, we strive in the end to secure complete series of stages which will positively link up the earliest larva with the parent form.

The adult fish is usually so very different in coloration, body proportions, and general characters from the younger stages that existing descriptions are often worthless. It seemed wise to attempt a collection of postlarvæ and young adults which might form a connecting link between the very tiny specimens caught in our nets and the older known adults. The Erie-Niagara watershed survey staff of the New York State Conservation Department gave us valuable cooperation in 1928, bringing in 37 species of small fishes. We adopted a special form of description and card-catalogued all species in this way. Thus additional data were recorded, such as the myomere count and chromatophore marking previous to the appearance of scales, which are invaluable for work on the earlier developmental stages.

EXPLANATIONS

At the beginning of the Lake Erie survey it was agreed, for uniformity among the various workers, to use the names of species as they were stated in "A Check-List of the Fishes of the Great Lakes and Tributary Waters, with Nomenclatorial Notes and Analytical Keys," by Carl L. Hubbs, University of Michigan, Museum of Zoology, Miscellaneous Publication No. 15, 1926. Hubbs's nomenclature, therefore, has been used in the present paper, but where the names given certain species in "Check List of the Fishes and Fishlike Vertebrates of North and Middle America North of the Northern Boundary of Venezuela and Colombia," by David Starr Jordan, Barton Warren Evermann, and Howard Walton Clark, U. S. Bureau of Fisheries Document No. 1055, Washington, 1930, differed from that previous list, the later name has been added in brackets below the one used by Hubbs.

Unless otherwise stated, all descriptions and drawings have been made from preserved specimens. Preservation was necessary because the collections in most cases could not be studied until the end of each cruise. The use of weak formalin, however, caused only slight shrinkage, and, except for some opacity, no visible change in the specimens occurred.

In describing the pigmentation of young fishes, the word "subsurface" is frequently used in reference to those chromatophores which lie below the outer surface, such as those distributed often over the air bladder or the intestinal tract. When the specimen has been rendered very opaque by growth or preservation, these pigment spots are not readily seen. Use of the transparency Method III described on page 297, however, will usually make them visible.

The word "incomplete" following a fin-ray count in young specimens means that the fin is not wholly developed and therefore the formula is incomplete.

ACKNOWLEDGMENTS

I am deeply grateful to Vernon S. L. Pate, artist of the report during the three summers of the Lake Erie investigation; and to Dr. Charles J. Fish, director of the cooperative survey, for certain drawings contained in this report, and for continued assistance and helpful suggestions throughout the duration of the work.

I am indebted to E. L. Wickliff and Prof. T. L. Hankinson for data and collections; Dr. John Van Oosten for a very large and complete series of young whitefish; J. L. Hart for whitefish, herring, perch, pike-perch, and muskalonge; J. P. Snyder for

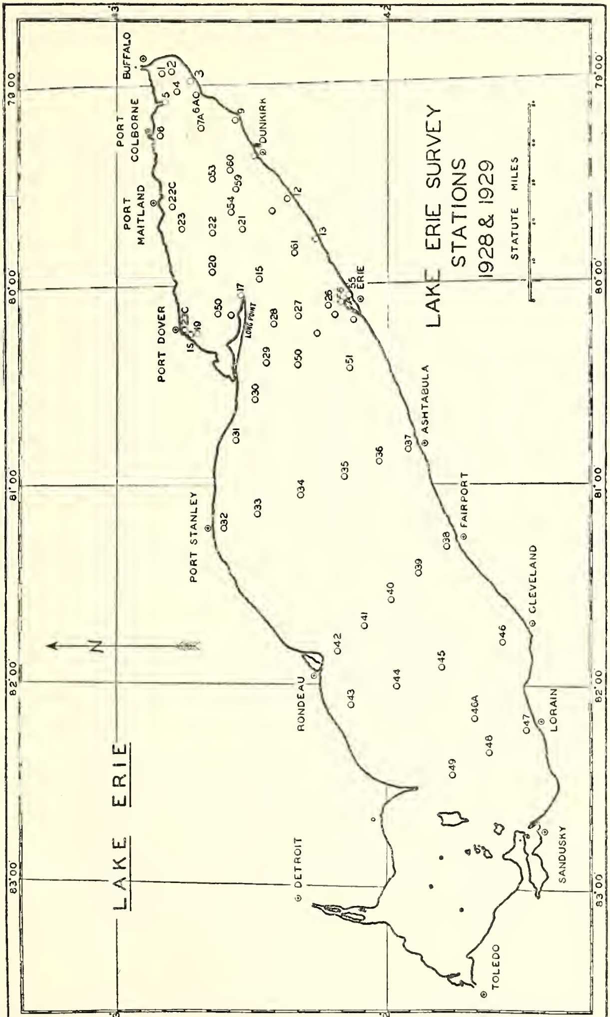

FIGURE 1.—Stations of the cooperative survey of Lake Erie in 1928 and 1929

herring, whitefish, lake trout, black bass, and brook-trout eggs and larvæ; Dr. Emmeline Moore for muskalonge eggs and larvæ; Miss Ida Mellen for brook-trout eggs; F. B. Voegele for whitefish and lake-trout eggs; and A. P. Miller for muskalonge larvæ.

Many notes on distribution and breeding of stream species were supplied through the kindness of Dr. John Greeley.

Table 1.—*Record of species of young fishes taken by Shearwater and Navette in 1928*

Species	Number of specimens	Length of specimens, millimeters	Record of capture			
			Depth, meters	Station [1]	Net	Date
Lepisosteus osseus	1	41	0	Navette dock, Buffalo	Dip	July 12
Catostomus commersonii	2	15	6	6A	Meter	June 12
	1	15	3	8A	do	Do.
	30	14–21	0	Sturgeon Point	Dip	June 13
	11	20.5	0	Navette dock, Grand Island.	do	July 9
	42	24.5	0		Seine	Do.
Moxostoma aureolum	1	8	6	13A	Meter	July 11
Notropis hudsonius	Many.	Ripe adults.	0	Sturgeon Point	Dip	June 13
	1	5.2	5	4A	Helgoland	July 12
Notropis atherinoides	1	6.4	60	01.15	Meter	July 30
	1	6.5	17	01.17	do	July 31
	2	4.6–5.5	9	01.18	do	Do.
	2	6.7–9.0	10	01.19	do	Do.
	1	16.5	23	05.12	do	Sept. 1
	2	16–17	0	05.15	Dip	Do.
Perca flavescens	Many.	5.5–12.5	4	4A	Meter	June 12
	14	6.5–13	4	4A	Helgoland	Do.
	23	6–11	6	6A	Meter	Do.
	6	6–12	3	8A	do	Do.
	1	9.2	3	8A	Helgoland	Do.
	2	6.5–9.6	4	17C	Meter	June 13
	2	7–8	6	11A	Helgoland	July 11
	631	[2] 40	8	02.02	Petersen	Aug. 8
	212	[2] 40	20	02.04	do	Do.
Percopsis omiscomaycus	6	7.5	7	7A	Helgoland	June 12
	3	6.3–6.5	3	8A	do	Do.
	1	6	3	8A	Meter	Do.
	1	6.3	6	11A	Helgoland	July 11
	1	9.7	14	01.05	Meter	July 26
	1	6.5	60	01.15	do	July 30
	7	17–25	20	02.04	Petersen	Aug. 8
	1	16	20	02.13	Helgoland	Aug. 9
	1	35	50	02.21	Meter	Aug. 10
Stizostedion canadense griseum	1	15.2	60	01.15	do	July 30
Boleosoma nigrum nigrum	Eggs.	1.4–1.5	0	Sturgeon Point	Dip	June 11
	3	35	7	7A	Helgoland	June 12
	1	5.6	17	14A	do	July 11
	1	14.5	25	02.04	do	Aug. 8
	6	7.5–15.5	16	02.09	do	Do.
Percina caprodes zebra	1	62	15	02.05	Petersen	Do.
	1	25.5	8	02.11	do	Aug. 9
	1	25.5	40	02.17	Helgoland	Do.
Micropterus dolomeiu	6	9.5–10	6	11A	do	July 11
Aplodinotus grunniens	1	13.3	17	03.24	Meter	Aug. 16
Cottus hairdii kumlieni	1	9.7	10.5	3A	Helgoland	June 11
Cottus cognatus	2	21–21.5	20	02.04	Petersen	Aug. 8
	1	20	23	02.23	Helgoland	Aug. 10
	1	33.5	20	04.11	do	Aug. 22
	1	22	20	04.12	do	Aug. 23
	1	35	20	04.13	do	Do.
	1	18.5	16	04.25	do	Aug. 25
Cottus ricei	1	27.5	22	04.23	do	Do.
Triglopsis thompsoni	1	13	60	01.15	Meter	July 30
	1	16	20	02.13	Helgoland	Aug. 9
	2	12.5–14	38	02.20	do	Aug. 10
	1	14	33	02.22	do	Do.
Lota maculosa	1	5.8	6	6A	Meter	June 12
	3	3–7.1	15	22C	do	June 18
	1	6.2	5	23C	do	June 19
	2	6–7	14	25C	do	June 20
	14	7–14	60	01.15	do	July 30
	1	10.5	32	01.20	do	Aug. 1
	4	11.5–15	34	01.22	do	Do.
	1	11.5	50	02.15	do	Aug. 9
	4	30.5	--------	Long Point Bay	Seine	Aug. 22

[1] Numbers in this column refer to the stations indicated in fig. 1. The Navette stations are shown by a whole number followed by the letter A or C, indicating American or Canadian inshore waters. The Shearwater stations follow the method commonly used in oceanographic work where the number of the cruise is placed immediately before the decimal point with station number following. This 01.15 means: Shearwater cruise 1, station 15.

[2] Approximate.

TABLE 2.—*Station record of young fishes taken by Shearwater and Navette in 1928*

Station	Net	Date	Species	Number of specimens	Length of specimens, millimeters
3A	Helgoland	June 11	Cottus bairdii kumlieni	1	9.7
4A	Meter	June 12	Perca flavescens	36	5.5–12.5
4A	Helgoland	do	do	14	6.5–13
6A	Meter	do	do	17	6–11
			Lota maculosa	1	5.8
			Catostomus commersonii	2	15
			Notropis atherinoides	1	34
7A	Helgoland	do	Percopsis omiscomaycus	6	7.5
			Boleosoma nigrum nigrum	3	Ripe adults.
8A	Meter	do	Perca flavescens	6	6–12
			Percopsis omiscomaycus	1	6
			Notropis atherinoides	11	(1)
			Catostomus commersonii	1	15
8A	Helgoland	do	Percopsis omiscomaycus	3	6.3–6.5
			Perca flavescens	1	9.2
17C	Meter	June 13	do	2	6.5–9.6
Sturgeon Point	Dip	do	Catostomus commersonii	30	14–21
			Notropis hudsonius	Many.	Ripe adults.
			Notropis atherinoides	Many.	Adults.
Buffalo Harbor	do	do	do	Many.	Do.
Crystal Beach	do	do	do	Few.	Do.
22C	Meter	June 18	Lota maculosa	3	3–7.1
23C	do	June 19	do	1	6.2
			Perca flavescens	3	5.3–6.2
25C	do	June 20	Lota maculosa	2	6–7
			Perca flavescens	1	8.8
11A	Helgoland	July 11	do	2	7–8
			Percopsis omiscomaycus	1	6.3
			Micropterus dolomieu	6	9.5–10
			Egg No. a	2	1.55–1.6
13A	Meter	do	Moxostoma aureolum	1	8
14A	Helgoland	do	Boleosoma nigrum nigrum	1	5.6
4A	do	July 12	Notropis budsonius?	1	5.2
01.05	Meter	July 26	Percopsis omiscomaycus	1	9.7
01.15	Meter—0m	July 30	Notropis atherinoides	1	6.4
	60m	do	Stizostedion canadense griseum	1	15.2
			Triglopsis thompsoni	1	13
			Percopsis omiscomaycus	1	6.5
			Lota maculosa	14	7–14
01.17	Meter	July 31	Notropis atherinoides	1	6.5
01.18	do	do	do	2	4.6–5.5
01.19	do	do	do	2	6.7–9
01.20	do	Aug. 1	Lota maculosa	1	10.5
01.22	do	do	do	4	11.5–15
02.02	Petersen	Aug. 8	Perca flavescens	631	2.40 [2]
02.04	do	do	do	212	2.40 [2]
			Notropis atherinoides	7	47
			Cottus cognatus	2	17
			Percopsis omiscomaycus	7	18
02.04	Helgoland	do	Boleosoma nigrum nigrum	1	14.5
02.05	Petersen	do	Percina caprodes zebra	1	62
02.09	Helgoland	do	Boleosoma nigrum nigrum	6	7.5–15.5
02.11	Petersen	Aug. 9	Percina caprodes zebra	1	2.25 [2]
02.13	Helgoland	do	Percopsis omiscomaycus	1	16
			Triglosis thompsoni	1	16
			Egg No. b	4	2.1–2.3 2.1–2.3
02.15	Meter	do	Lota maculosa	1	11.5
02.17	Hegoland	do	Percina caprodes zebra	1	25.5
02.20	do	Aug. 10	Triglopsis thompsoni	2	12.5–14
02.21	Meter	do	Percopsis omiscomaycus	1	35
02.22	Helgoland	do	Triglopsis thompsoni	1	14
02.23	Meter	do	Cottus cognatus	1	20
03.24	do	Aug. 17	Aplodinotus grunniens	1	13.3
04.11	Helgoland	Aug. 22	Cottus cognatus	1	33.5
04.12	do	Aug. 23	do	1	22
04.13	do	do	Lota maculosa	1	19
			Cottus cognatus	1	35
04.23	do	Aug. 25	Cottus ricei	1	27.5
04.25	do	do	Cottus cognatus	1	18.5
05.12	Meter	Sept. 1	Notropis atherinoides	1	16.5
05.15	Dip	do	do	2	16–17

[1] Young adults up to 34 millimeters. [2] Approximate.

TABLE 3.—*Record of young fishes taken by Shearwater in 1929*

Species	Number of specimens	Length of specimens, millimeters	Record of capture		
			Station	Net	Date
Moxostoma aureolum	1	8.4	06.03	Bottom meter	Aug. 6
Cyprinus carpio	11	9.5–17.5	Crescent Beach	Bottom dip	June 29
Erinemus storerianus	1	5	02.30	Bottom meter	June 15
	1	5	02.35	do	June 16
	1	5.7	02.42	do	June 17
	2	6–7.5	04.04	do	July 2
	1	6	04.12	Surface meter	July 5
Rhinichthys cataracatae	1	12.5	Crescent Beach	Bottom foot	June 29
Notropis deliciosus stramineus	1	6.8	06.03	Surface meter	Aug. 6
	2	6–8.5	06.07	Bottom meter	Do.
	1	6.2	06.19	do	Aug. 8
	4	6–10.5	06.20	Surface meter	Do.
	38	5.5–8.9	06.47	Bottom meter	Aug. 19
	85	4.9–10	06.47	Surface meter	Do.
Notropis atherinoides	1	6.7	04.03	do	July 2
	1	6.7	04.11	Bottom meter	July 5
	4	7	04.12	Surface meter	Do.
	1	13	04.36	do	July 11
	72	5–7	04.38	do	July 12
	174	5–7	04.38	Bottom meter	Do.
	1	7	04.43	Surface meter	July 13
	25	6.8–8.4	04.43	Bottom meter	Do.
	8	6.5–9.5	04.47	Surface meter	July 15
	14	6–10.5	04.47	Bottom meter	Do.
	47	6–7	04.48	Surface meter	Do.
	39	4.5–6.5	04.49	Bottom meter	Do.
	480	10.5–22	05.13	Surface meter	July 23
	115	10.5–17.5	05.14	do	Do.
	4	19–20	06.03	do	Aug. 6
	1	10	06.04	Bottom meter	Do.
	1	12.2	06.05	Surface meter	Do.
	5	9–13	06.07	Bottom meter	Do.
	5	9–12	06.12	Surface meter	Aug. 8
	4	11.5–26	06.12	Dip	Do.
	77	5	06.13	Surface meter	Aug. 10
	80	14–29.5	06.13	Dip	Do.
	1	19	06.20	Surface meter	Aug. 8
	12	5.6–12	06.26	do	Aug. 13
	9	23.5–30	06.37	Dip	Aug. 16
	17	12–20	06.38	do	Aug. 17
	1	10.3	06.38	Surface meter	Do.
	100	[1] 14	06.39	Dip	Do.
	116	11–14	06.40	do	Do.
	117	11–15	06.41	do	Do.
	9	6.5–14.5	06.41	Surface meter	Do.
	3	9.5–12	06.42	do	Do.
	138	7–15.5	06.43	Dip	Aug. 18
	1	16.5	06.44	Surface meter	Do.
	4	7.5–9	06.46	do	Do.
	100	12.5–24	06.46	Dip	Do.
	13	4.8–32	06.47	Surface meter	Aug. 19
	46	7.5–17.5	06.47	Dip	Do.
	5	12–16	06.48	do	Aug. 20
	23	8–12.5	06.48	Surface meter	Do.
	21	5–7.2	06.49	Bottom meter	Do.
	81	5–11	06.49	Surface meter	Do.
Notropis cornutus chrysocephalus	1	6	02.49	do	June 19
	9	6	04.17	do	July 8
Fundulus diaphanus menona	6	7.2–12.5	Crescent Beach	Bottom meter, depth, 3 feet.	June 29
Percopsis omiscomaycus	1	8.4	04.38	Bottom meter	July 12
	4	6	04.42	Surface meter	July 13
Perca flavescens	17	6–12	02.02	Bottom meter	June 7
	6	6.5–6.7	02.03	do	Do.
	3	7.2	02.09	Surface meter	June 8
	6	6.5–7.2	02.09	Bottom meter	Do.
	1	6.3	02.11	do	June 10
	5	6–6.5	02.29	do	June 15
	3	5.5–6.5	02.30	do	Do.
	3	5.6–9	02.31	do	Do.
	2	6–6.5	02.51	Surface meter	June 14
	1	7.6	02.52	do	June 11
	5	5–6.7	02.32	do	June 16
	1	6.7	02.33	Bottom meter	Do.
	1	6	02.34	do	Do.
	1	6	02.35	do	Do.
	118	5.6–10	02.42	do	June 17
	1	15	02.47	Surface meter	June 19
	8	9.5–16	02.47	Bottom meter	Do.
	1	13	04.04	do	July 2
	17	6–10.8	04.06	Surface meter	Do.
	1	10.5	04.06	Bottom meter	Do.
	1	12	04.11	do	July 5
	1	12.6	04.12	Surface meter	Do.
	2	14.8–17.5	04.17	Bottom meter	July 8
	9	7.8–14.5	04.32	do	July 11
	1	6	04.35	do	Do.
	1	50	06.03	do	Aug. 6

[1] Approximate.

TABLE 3.—*Record of young fishes taken by Shearwater in 1929*—Continued

Species	Number of specimens	Length of specimens, millimeters	Record of capture		
			Station	Net	Date
Percina caprodes zebra	1	7	06.49	Bottom meter	Aug. 20
Rheocrypta copelandi	2	6	02.05	do	June 7
Cottus bairdii kumlieni	2	6–7	02.02	do	Do.
	1	10.4	02.11	do	June 10
	3	6.5–8	02.29	do	June 15
	10	6.5–7.5	02.30	do	Do.
	5	7–9	02.31	do	Do.
	2	6.5	02.32	Surface meter	June 16
	2	6–8	02.33	Bottom meter	Do.
	5	6–11	02.34	do	Do.
	5	5.8–8	02.42	do	June 17
	2	7.5–9	02.43	do	June 18
	1	10	02.44	do	Do.
	1	10.3	02.48	do	June 19
	2	11.5	04.17	do	July 8
	1	11.5	04.34	do	July 11
Lota maculosa	5	4.1–6	02.02	do	June 7
	2	5.6–6.2	02.03	do	Do.
	2	5	02.05	do	Do.
	1	6.2	02.09	Surface meter	June 8
	1	4.5	02.09	Bottom meter	Do.
	4	4.5–6.2	02.12	Surface meter	Do.
	3	6.3–7	02.14	do	Do.
	2	7–9	02.29	Bottom meter	June 15
	10	5.2–8.6	02.30	do	Do.
	3	6.5–8.1	02.31	do	Do.
	7	5.1–8	02.50	do	Do.
	29	4–7.2	02.51	Surface meter	June 14
	2	6–7	02.51	Bottom meter	Do.
	3	7–8	02.33	do	June 16
	4	6.5–8.5	02.34	do	Do.
	5	4.5–9	02.36	do	Do.
	5	4–8	02.42	do	June 17
	1	12	02.44	do	June 18
	3	10–13	04.21	do	July 5

TABLE 4.—*Station record of young fishes taken by Shearwater in 1929*

Station	Net	Date	Species	Number of specimens	Length of specimens, millimeters
02.02	Bottom meter	June 7	Perca flavescens	17	6–7
			Cottus bairdii kumlieni	2	6–7
			Lota maculosa	5	4.1–6
02.03	do	do	Perca flavescens	6	6.5–6.7
			Lota maculosa	2	5.6–6.2
02.05	do	do	do	2	5
			Rheocrypta copelandi	2	6
02.09	Surface meter	June 8	Perca flavescens	3	7.2
			Lota maculosa	1	6.2
02.09	Bottom meter	do	Perca flavescens	6	6.5–7.2
			Lota maculosa	1	4.5
02.11	do	June 10	Perca flavescens	1	6.3
			Cottus bairdii kumlieni	1	10.4
02.12	Surface meter	June 8	Lota maculosa	4	4.6–6.2
02.14	do	do	do	3	6.3–7
02.29	Bottom meter	June 15	do	2	7–9
			Perca flavescens	5	6–6.5
			Cottus bairdii kumlieni	3	6.5–8
02.30	do	do	do	10	6.5–7.5
			Lota maculosa	10	5.2–8.6
			Perca flavescens	3	5.5–6.5
			Erinemus storerianus	1	5
02.31	do	do	Lota maculosa	3	6.5–8.1
			Cottus bairdii kumlieni	5	7–9
			Perca flavescens	3	5.6–9
02.32	Surface meter	June 16	do	5	5–6.7
			Cottus bairdii kumlieni	2	6.5
02.33	Bottom meter	do	Perca flavescens	1	6.7
			Cottus bairdii kumlieni	2	6–8
			Lota maculosa	3	7–8
02.34	do	do	Perca flavescens	1	6
			Lota maculosa	4	6.5–8.5
			Cottus bairdii kumlieni	5	6–11
02.35	do	do	Erinemus storerianus	1	5
			Perca flavescens	1	6
02.36	do	do	Lota maculosa	5	4.5–9

TABLE 4.—*Station record of young fishes taken by Shearwater in 1929*—Continued

Station	Net	Date	Species	Number of specimens	Length of specimens, millimeters
02.42	do	June 17	Perca flavescens	118	5.6–10
			Lota maculosa	5	4–8
			Cottus bairdii kumlieni	5	5.8–8
			Erinemus storerianus	1	5.7
02.43	do	June 18	Cottus bairdii kumlieni	2	7.5–9
02.44	do	do	Lota maculosa	1	12
			Cottus bairdii kumlieni	1	10
02.47	Surface meter	June 19	Perca flavescens	1	15
02.47	Bottom meter	do	do	8	9.5–16
02.48	do	do	Cottus bairdii kumlieni	1	10.3
02.49	Surface meter	do	Notropis cornutus chrysocephalus	1	6
02.50	Bottom meter	June 15	Lota maculosa	7	5.1–8
02.51	Surface meter	June 14	do	29	4–7.2
			Perca flavescens	2	6–6.5
02.51	Bottom meter	do	Lota maculosa	2	6–7
02.52	Surface meter	June 11	Perca flavescens	1	7.6
Crescent Beach	Bottom meter, depth, 3 feet	June 29	Rhinichthys cataractae	1	12.5
			Fundulus diaphanus menona	6	7.2–12.5
			Cyprinus carpio	11	9.5–17.5
04.03	Surface meter	July 2	Notropis atherinoides	1	6.7
04.04	Bottom meter	do	Perca flavescens	1	13
			Erinemus storerianus	2	6–7.5
04.06	Surface meter	do	Perca flavescens	17	6–10.8
04.06	Bottom meter	do	do	1	10.5
04.11	do	July 5	do	1	12
			Notropis atherinoides	1	6.7
04.12	Surface meter	do	Erinemus storerianus	1	6
			Perca flavescens	1	12.6
			Notropis atherinoides	4	7
04.17	do	July 8	Notropis cornutus chrysocephalus	9	6
04.17	Bottom meter	do	Cottus bairdii kumlieni	2	6–11.5
			Perca flavescens	2	14.8–17.5
04.21	do	July 5	Lota maculosa	3	10–13
04.32	do	July 11	Perca flavescens	9	7.8–14.5
04.34	do	do	Cottus bairdii kumlieni	1	11.5
04.35	do	do	Perca flavescens	1	6
04.36	Surface meter	do	Notropis atherinoides	1	13
04.38	do	July 12	do	72	5–7
04.38	Bottom meter	do	do	174	5–7
			Percopsis omiscomaycus	1	8.4
04.42	Surface meter	July 13	do	4	6
04.43	do	do	Notropis atherinoides	1	7
04.43	Bottom meter	do	do	25	6.8–8.4
04.47	Surface meter	July 15	do	8	6.5–9.5
04.47	Bottom meter	do	do	14	6–10.6
04.48	Surface meter	do	do	47	6–7
04.49	Bottom meter	do	do	39	4.5–6.5
05.13	Surface meter	July 23	do	480	10.5–22
05.14	do	do	do	115	10.5–17.5
06.03	do	Aug. 6	Moxostoma aureolum	1	8.4
			Notropis deliciosus stramineus	1	6.8
			Notropis atherinoides	4	19–20
06.03	Bottom meter	do	Perca flavescens	1	50
06.04	do	do	Notropis atherinoides	1	10
06.05	Surface meter	do	do	1	12.2
06.07	Bottom meter	do	do	5	9–13
			Notropis deliciosus stramineus	2	6–8.5
06.12	Surface meter	Aug. 8	Notropis atherinoides	9	9–26
06.13	do	Aug. 10	do	157	5–29.5
06.19	Bottom meter	Aug. 8	Notropis deliciosus stramineus	1	6.2
06.20	Surface meter	do	do	1	10.5
			Notropis atherinoides	1	19
06.26	do	Aug. 13	do	12	5.6–12
06.37	do	Aug. 16	do	9	23.5–30
06.38	do	Aug. 17	do	18	10.3–20
06.39	do	do	do	100	[1]14
06.40	do	do	do	116	11–14
06.41	do	do	do	126	6.5–14.5
06.42	do	do	do	3	5–12
06.43	do	Aug. 18	do	138	7–15.5
06.44	do	do	do	1	16.5
06.46	do	do	do	100	12.5–24
06.47	do	Aug. 19	do	59	4.8–32
			Notropis deliciosus stramineus	85	4.9–10
06.47	Bottom meter	do	do	38	5.5–8.9
06.48	Surface meter	Aug. 20	Notropis atherinoides	28	8–16
06.49	do	do	do	81	5–11
06.49	Bottom meter	do	do	21	5–7.2
			Percina caprodes zebra	1	7

[1] Approximate.

NUMERICAL SYNOPSIS OF SPECIMENS EXAMINED

Before discussing the species in detail, the following numerical synopsis is given: In 1928, the *Shearwater* and *Navette* plankton nets and young fish trawls yielded 1,049 specimens, representing 18 species. Supplementary collections from hatcheries, streams, and alongshore numbered about 49 more, making a total of 67 species for which descriptions of young forms have been made.

The *Shearwater* collections in 1929 yielded 2,235 specimens, or more than double the number taken in 1928, representing 14 species. Six of these species were not taken previously by the Lake Erie collecting party, and 10 species captured by the *Shearwater* during the same period in 1928 were not among the later collections. Thus, the accidental aspect of our collecting methods and the need for carrying on studies over several years with young-fish nets of every description are strikingly emphasized.

The collections examined in 1930, which had been taken during the previous year in the western part of Lake Erie along the Ohio shore, numbered over 20,000 individuals, representing 17 species.

Counting several new records of distribution added by the present investigation to previous faunal lists of the region, there have been reported 112 species from the Erie-Niagara watershed, 92 of which are found in Lake Erie. Practically all of those species not taken by the cooperative survey are of extremely rare occurrence, and many are represented by a single record which may be questionable.

DEVELOPMENT OF SPECIES

Family LEPISOSTEIDÆ, Gar-pikes

1. Lepisosteus osseus Linnaeus. Long-nosed gar; gar-pike; bill-fish.

RECORD OF CAPTURE

One young fish, 41 millimeters long, was dipped from the surface at Buffalo on July 12, 1928. Adults are moderately common in Lake Erie and the Niagara River.

DESCRIPTION

The young are easily recognized by the greatly prolonged toothed jaws and elongate body, brilliant in seal, reddish-brown, and bronze.

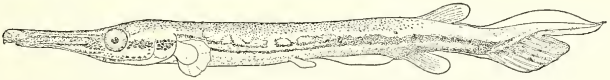

FIGURE 2.—*Lepisosteus osseus*, 41 millimeters

41.0-millimeter stage.—Dorsal, 7; anal, 7 (incomplete). Total length, 41.0; length of head, 12.0; length to vent, 27.5; length to dorsal, 29.0; greatest depth, 3.0; diameter of eye, 3.0 millimeters.

The most remarkable feature of this small and brilliant gar was the prolongation of the notochord into a fleshy filament, apart from the caudal fin, which kept up a rapid vibratory motion. That the caudal fin is not the true termination of the vertebral column, but an appendage to its lower portion, "a true second anal," is thus strikingly demonstrated.

Pigmentation.—There are three distinct shades of brown in the living specimen, which may be described as a dark seal-brown, reddish-brown, and bronze. The bronze has some metallic sheen and the lightest intensity of all. The dorsal surface is covered with closely distributed, tiny, round, reddish-brown chromatophores, those on the prolonged jaws being larger, stellate, and fewer toward the center line. Viewed from the side, some exceptionally large seal-brown chromatophores appear on jaws extending to eye, a narrow line encircling orbit, and thence a broad band of bronze to the posterior margin of head. On either side of this postorbital band is a white band, met above by the reddish-brown dorsal region and below by the dark ventral chromatophores. Behind the head, dorsal chromatophores extend down the sides for one-third of their depth, continuing to extreme tip of body on either side of notochord. Below this is an irregular white band with a very broken bronze band interposed upon it, followed below by a wide median band of deep seal-brown and bronze extending the full length of body, continued to top of lower part of caudal fin. Below the median band, a white band is apparent, which becomes narrower and is lost behind the anal fin, bounded below by the seal-brown ventral region. The underside is characterized by the same white color as the sides (as a pigment, not the opaque, colorless white of young forms). An arrow-shaped patch of white marks the lower surface of head, and behind this the ventral aspect is mostly seal-brown with only small irregular markings of white. Base of pectorals is white with a median-brown band about one-third the width of the base, not extending to tip of fin. Some reddish-brown is evident on dorsal, and the brown ventral chromatophores extend out less than half the distance to tip of anal fin.

BREEDING

The long-nosed gar spawns in late spring and early summer in warm shoal water, often running up smaller streams in company with the sturgeons. The eggs are probably attached to weeds, and the young remain among the weed beds close inshore during their first summer.

Family HIODONTIDÆ, Mooneyes

2. Hiodon tergisus Le Sueur. Mooneye; toothed herring.

RECORD OF CAPTURE

None of this species were taken by townets in the deeper waters of eastern Lake Erie during the survey, but schools of young were found at many places close inshore and at creek mouths. Among the 1929 collections from the western end of Lake Erie were eight larvæ, 12.0 to 15.5 millimeters in length, taken on June 7 at the surface in water of 15 to 19 feet. A 6.5-millimeter larva which seems to be identical with the above was taken on June 10, off the mouth of the Maumee River.

DESCRIPTION

The elongate herringlike body with blunt projecting snout and large mouth at all stages is unlike any other species taken by the survey.

6.5-millimeter stage.—Total length, 6.5; standard length, 6.3; length to vent, 4.3; length of head, 1.16; diameter of eye, 0.3; greatest depth before vent, 0.85; depth behind vent, 0.4 millimeter. Myomeres incomplete at beginning and end of body but

probably about 28 to vent, plus 16 behond. Body very slender and elongate with bulbous forehead; terminal mouth placed very low, with gape to front margin of pupil; pectorals developed by unrayed; marginal fin fold arising dorsally at about sixteenth myomere behind head, low, but slightly higher above vent, very low around caudal, and continued on underside forward past vent to middle of intestine. Although the notochord still is straight, lower caudal rays are developing.

Pigmentation.—Body is colorless except for partially pigmented eyes.

Although the myomere count is somewhat shorter, there are certain very important characters of this larva which seem to indicate that it is identical with the species

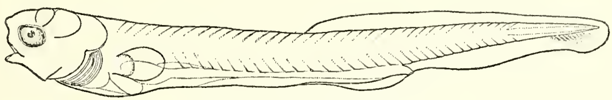

FIGURE 3.—*Hiodon tergisus*, 6.5 millimeters

represented by the 14.2-millimeter specimen, which is the subject of the next description. The exceptionally protruding snout, very large mouth, small eye, elongate body with vent situated far back, posterior insertion of dorsal marginal fin fold with slight elevation above vent, unusually low marginal fin fold around caudal with rays forming in this fin before the notochord bends upward, all point to its identification as *Hiodon tergisus*. The very early stage of the larva may account for the incompleteness of myomeres, and thus it is tentatively assigned to this species.

14.2-millimeter stage.—Total length, 14.2; standard length, 13.2; length to vent, 9.0; length of head, 2.5; snout, 0.6; diameter of eye, 0.85; greatest depth before vent, 2.0; depth behind vent, 1.0 millimeter. Myomeres, 30 to vent plus 21–23 behind. Contour of dorsal fin indicated with elements of 12 dorsal rays and about 20 anal

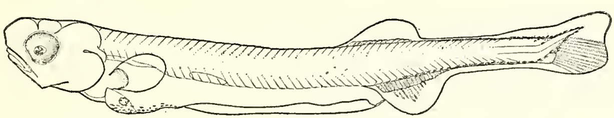

FIGURE 4.—*Hiodon tergisus*, 14.2 millimeters

elements apparent; lower caudal rays developed although tail not yet completely heterocercal. Slender, oblong body; blunt snout much protruding, so that mouth is inferior; lower jaw included; premaxillaries and maxillaries very slender; gape of mouth to distal margin of pupil; wide set, cardiform teeth in premaxillaries, and mandibles proportionately larger at this state than in adult; nostrils large, close together.

Pigmentation.—Brownish chromatophores appear on the ventral surface below the large, anteriorly placed oil globule, and along yolk region a quarter of the distance to vent. A few widely separated subsurface spots are present along dorsal aspect of stomach region. An irregular double line of small chromatophores is seen on dorsal margin from dorsal fin to caudal, and a single partially subsurface series on ventral margin from shortly behind vent to caudal. Small pigment spots are distributed at base of caudal.

BREEDING

Apparently this species was spawning in our region about the first of June. The eggs are known to fall into the abdominal cavity before extrusion, rather than into ducts leading from the ovaries to the outside, as is the case in most fishes (Bean, T. H., 1903).

Family COREGONIDÆ, Whitefishes

3. Leucichthys artedi (Le Sueur). Lake herring; cisco.

RECORD OF CAPTURE

No young herring were taken by the survey during the summers of 1928 and 1929. By the time our collecting trips started the herring had grown to a stage where they were able successfully to escape the trawls used. Consequently, it was necessary to rely upon rather scanty formalin-preserved hatchery material for a study of this species. The following short account will serve only as preliminary data toward a complete developmental history to be made later.

DESCRIPTION

Egg.—Diameter of preserved hatchery specimens examined varying from 2.0 to 2.5 millimeters, mostly 2.25 millimeters. The earliest stage obtained measured

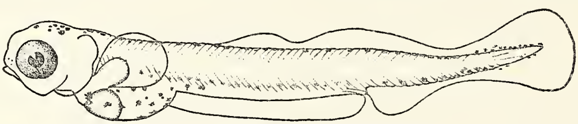

FIGURE 5.—*Leucichthys artedi,* 10.25 millimeters

2.25 millimeters, diameter of yolk, 1.8 millimeters, with a colorless early embryo reaching halfway around the yolk. Myomeres faintly discernible.

Pigmentation.—The eggs, although very opaque from preservation, show about 20 rather large oil globules, deep amber in color on the yellowish yolk. In a later stage when the embryo reaches more than once and a half around the yolk and is apparently ready to hatch, the top of head becomes heavily pigmented and dorsal and ventral brown stripes, characteristic of the newly hatched larva, are prominent. Yolk sac is deep yellow, its anterior part filled with a large oil globule, and dark thickly distributed chromatophores make their appearance on the underside posteriorly. Eyes are dark, and the center of head behind eyes is covered by a diamond-shaped patch of small chromatophores. Chromatophores continue, small and stellate, to form the double dorsal series to end of body, with a similar ventral series behind the vent.

8.5–9.8-millimeter stage.—Newly hatched. Much like following specimen figured, but yolk sac larger and body proportionately more slender. Pigment identical with that of the 10.25-millimeter stage.

10.25-millimeter stage.—Age about 2 days. Total length, 10.25; length to vent, 6.8; greatest depth behind yolk sac, 0.85; diameter of eye, 0.9 millimeter; myomeres, 38 to vent plus 19 behind. Embryonic marginal fin fold complete, starting over seventeenth myomere, rising, then notching over twenty-ninth myomere, rising again

and notching at peduncle; ventrally starting beneath yolk sac, breaking completely at vent, and notching at peduncle; caudal lophocercal; pectorals large, rounded. Head very blunt, its highest point over posterior part of eye; mouth subinferior, jaws equal.

Pigmentation.—The larval *Leucichthys artedi* is opaque white in color, differing from *Coregonus clupeaformis* in the restriction of yellow color to the yolk, whereas in the latter this color is diffused in subsurface streaks about the head, above the

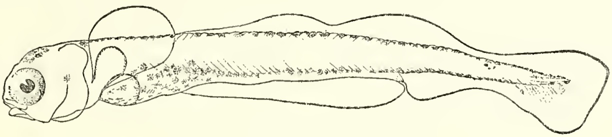

FIGURE 6.—*Leucichthys artedi*, 12.5 millimeters

stomach, and in some specimens over the whole body. In the specimen figured, 2 round areas of chromatophores appear on head followed by a double series of 18 along dorsal aspect to a point opposite vent, thence 24 to tip of tail. These two lines are not even, the chromatophores being sometimes alternate and differing in size and number, thus distinguishing the species from *Coregonus clupeaformis* in which the dorsal series usually are perfectly symmetrical. Lateral and ventral aspects of head are colorless. One very large stellate spot is apparent over pericardiac region at the beginning of the yolk sac. Behind this, two more or less definite lines extend across sac, and a few chromatophores, very linear in shape, are arranged longitudinally on underside of sac. Starting just before end of yolk sac, a series of about 20 large

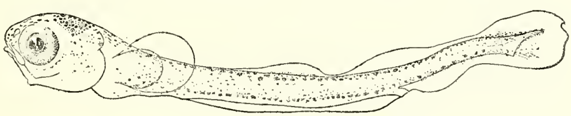

FIGURE 7.—*Leucichthys artedi*, 14.5 millimeters

stellate chromatophores occurs over intestine, and behind vent there is an uneven double line of about 12 intersprinkled with smaller ones to tip of tail.

12.5-millimeter stage.—Total length, 12.5; length to vent, 8.5; greatest depth, 1.6; diameter of eye, 1.0 millimeter; myomeres, 38 to vent plus 19 behind. Immediately after preceding stage yolk beginning to shrink, and at this stage represented by only a fragment showing yellowish through the body wall. Embryonic marginal fin fold unchanged; pectorals enlarged; notochord turning upward very slightly. Head less blunt than before; lower jaw slightly shorter.

Pigmentation.—The linear chromatophores on underside of yolk sac now are more numerous, giving a "pin feather" effect, and those on sides of sac have increased greatly in size and are remarkably stellate in shape; others appear unchanged. All specimens which have been examined show heavy dorsal pigment on head and at the beginning of dorsal ridge, then a break occurs in the series until shortly before vent during which space the chromatophores are quite sparsely distributed. Following the break they are closer together, more numerous, and form a very distinct band.

14.5-millimeter stage.—Total length, 14.5; length to vent, 10.6; length of head, 2.5; greatest depth (head), 1.92; diameter of eye, 1.25; maxillary, 1.1 millimeter. Embryonic marginal fin fold broken dorsally at twenty-ninth myomere and well separated from posterior portion; no rays evident but some concentration in the anterior portion, indicating later position of basal elements; ventrally marginal fin fold much reduced; caudal becoming heterocercal by dorsal extension of notochord, outer contour very slightly notched, and few rays suggested ventrally; no ventrals in this specimen, although development is beginning in another specimen only 13.2 millemeters long. Head more pointed; maxillary to middle of pupil.

Pigmentation.—Chromatophores have increased greatly on top of head, and a double series with 3 or 4 lines of smaller ones between occurs along dorsal ridge of body. There are more pigment spots on sides of body and on dorsal surface of intestine, both surface and subsurface, and a few extend on to caudal.

16.5 millimeter stage.—Total length, 16.5; standard length, 15.25; length to vent, 11.9; length of head, 3.5; length of maxillary, 1.4; diameter of eye, 1.5; greatest depth (head), 2.2; depth at stomach, 1.9; greatest depth behind vent, 0.82 millimeter. Nine dorsal elements and short rays; none in anal; caudal rays developing; small ventrals apparent directly beneath dorsal rays. Intestine still ending away from body

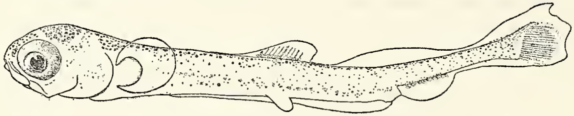

FIGURE 8.—*Leucichthys artedi*, 17.5 millimeters

at margin of embryonic fin fold. Body somewhat heavier than preceding. Pigmentation unchanged.

17.5-millimeter stage.—Total length, 17.5; length to vent, 12.3; length of head, 3.6; length of maxillary, 1.4; greatest depth (head), 2.3; diameter of eye, 1.5 millimeters. Elements complete and 10 dorsal rays visible; 10 anal elements but no rays; ventrals larger but not rayed.

BREEDING

The lake herring spawns in November and early December, coming into shallow water in vast schools for the purpose. The eggs incubate on the bottom during the long winter months, hatching the following spring, the exact date dependent upon the temperature of the waters.

4. Coregonus clupeaformis (Mitchill). Whitefish.

RECORD OF CAPTURE

As in the case of the lake herring, the late start of our collecting trips during the summers of 1928 and 1929 prevented the capture of eggs and early young of this species. The following notes are based on a series of preserved eggs obtained from E. L. Wickliff at Put-in-Bay, Ohio, and young from 7 days to 109 days from Dr. John Van Oosten, reared at the New York Aquarium. The later stages described were loaned by J. L. Hart.

DESCRIPTION

Egg.—Diameter after preservation in formalin mostly 2.8 to 3.0 millimeters; perfectly spherical, yolk yellowish or amber with half its surface covered by varying sized oil globules closely crowded together. Immediately after fertilization yolk entirely fills egg, with no perivitelline space apparent except at one pole. At 6 hours average diameter, 3.0; yolk diameter, 2.6 millimeters, with widened perivitelline space and the first concentration of germinal matter to form the blastodisc at center of oil globule mass. Blastodisc continues to form until the beginning of cleavage at 24 hours, when 2, 4, and 8 cell stages are apparent. Blastodisc lenticular by fifth day with oil globules congregated below. On twenty-sixth day an early embryo reaches halfway around egg and shows well developed optic vesicles which are slightly pigmented on inner and upper margins. Oil globules coalescing in part to form

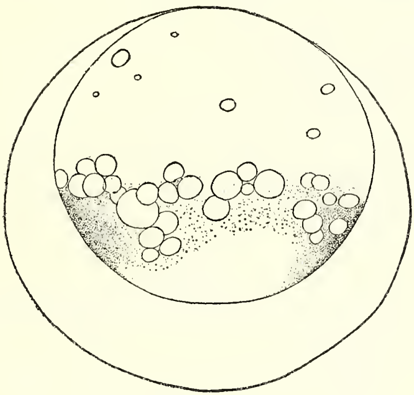

FIGURE 9.—*Coregonus clupeaformis* egg

usually about two very large spheres, with many small ones remaining. At 40 days the embryo extends completely around egg; head much higher and more rounded, eyes larger and black; 1 large oil globule and only a few smaller ones on yolk. First evidence of dorsal and ventral marginal pigmentation evident at 54 days.

Figure 10 shows the embryo in process of hatching on the sixty-first day. Mouth not open; vent at a distance from body, at edge of fin fold; embryonic marginal fin fold completely encircling fish from behind head around lophocercal tail to yolk sac; yolk sac very large, deep yellowish in color, with 1 large oil globule and other smaller ones. Myomeres completely formed. Double series of brown chromatophores on both dorsal and ventral aspects; yolk sac also pigmented posteriorly, near the body. Other eggs in collection not hatched at 131 days.

12.0-millimeter stage.—Less than 1 week old. Total length, 12.0; length to vent, 7.0; greatest depth behind yolk sac, 1.1; diameter of eye, 0.8 millimeter. Body much heavier, the greatest depth behind yolk sac being 10.9 in total length, while in a herring of equal development it is 12. Embryonic marginal fin fold resembling herring, originating over middle of yolk sac, notching somewhat about 11 myomeres before

the vent, rising again to highest point over vent, notching on either side of peduncle, and breaking entirely at vent.

Pigmentation.—The 12-millimeter whitefish is characterized by a large, very yellow yolk sac, and by much yellow diffused in subsurface streaks about the head,

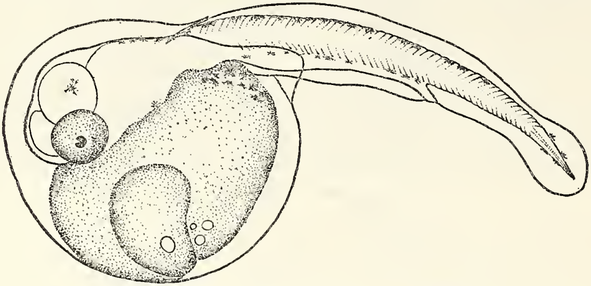

FIGURE 10.—*Coregonus clupeaformis* embryo in process of hatching

above the stomach, and in some specimens over the whole body, thus differentiating it from *Leucichthys artedi* in which this color is less intense and limited to the yolk sac. Chromatophores are distributed essentially as in the herring, but generally they are much larger, darker, and more regularly arranged, consisting of a few large

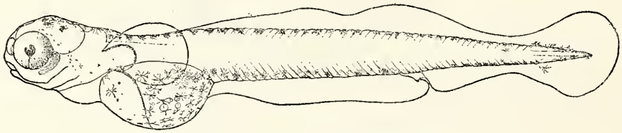

FIGURE 11.—*Coregonus clupeaformis*, 12 millimeters

black stellate spots on top of head and a few very small ones on sides, running into an unbroken double line of about 52 on dorsal aspect, which are very large and square ly stellate. Chromatophores appear on underside of head and continue in a line across yolk sac and on dorsal aspect of intestine to vent, numbering about 28 on each

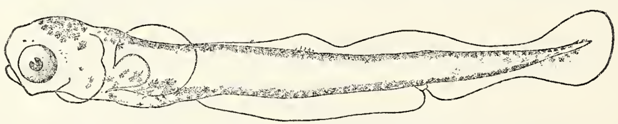

FIGURE 12.—*Coregonus clupeaformis*, 13.5 millimeters

side. Few others are spread over yolk sac, and a double ventral series of about 17, similar to dorsal, is apparent behind vent.

13.5-millimeter stage.—About 1 week old. Total length, 13.5; length to vent, 10.0; greatest depth, 1.6; diameter of eye, 1.25 millimeters. Embryonic marginal fin fold unchanged in shape from preceding stage, but now with slight suggestions of 5 dorsal fin rays in anterior part, pectorals very large; yolk almost completely absorbed.

Pigmentation.—There is still much yellow over yolk region, and whole head is tinged with yellow. Number and arrangement of chromatophores is as in 12-millimeter specimen described above, but the size of all chromatophores is increased until they overlap in marginal series.

18.5-millimeter stage.—Age unknown but similar to specimens 61 days old. Total length, 18.5; standard length, 17.0; length to vent, 13.25; length of head, 4.0; depth

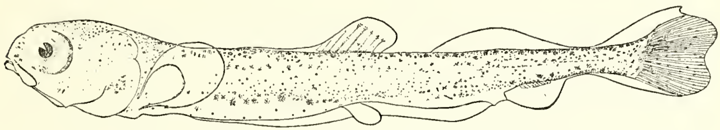

FIGURE 13.—*Coregonus clupeaformis*, 18.5 millimeters

of head, 2.25; greatest depth behind head, 2.0; diameter of eye, 1.6 millimeters. Dorsal rays fairly well developed; embryonic marginal fin fold starting again after wide space behind dorsal, continuing to caudal, complete on ventral side, with basal elements of anal fin developed but no rays; caudal slightly notched dorsally at end of notochord, lower portion becoming forked and rays well formed; ventrals prominent.

Pigmentation.—Dorsal and ventral series of chromatophores are still prominent, but many smaller ones have become scattered over sides of head, body and caudal.

22.0-millimeter stage.—65 days old. All fins fully developed with exception of adipose, in which region a large fragment of the embryonic fin fold remains.

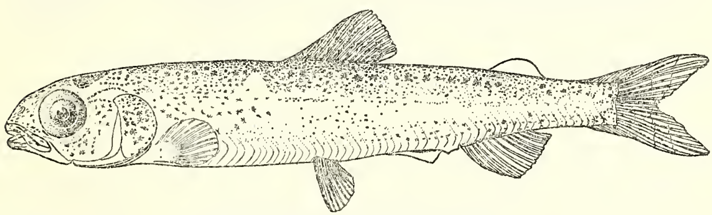

FIGURE 14.—*Coregonus clupeaformis*, 31.5 millimeters

31.5-millimeter stage.—Age unknown but similar to specimens 95 to 109 days old. Total length, 31.5; standard length, 27.0; length of head, 6.75; greatest depth of body, 4.5; diameter of eye, 2.0 millimeters. Assuming shape of adult.

Pigmentation.—The chromatophores are essentially as in younger specimens but they have become more diffused, with dorsal and ventral ridges of body from head to caudal still most deeply pigmented. Black, stellate, dorsal chromatophores continue down the sides of body to lateral line, becoming gradually smaller and wider apart. The lateral line is marked by closely distributed small black spots. A few chromatophores appear on ventral aspect of stomach; none beneath the intestine. The large areas of chromatophores behind eye are still noticeable, and many more, lighter in color, show between and before the eyes, becoming darker at mouth. Dorsal and caudal are speckled with black, following lines of rays. The body, and especially the head, are silvery at this stage.

Upon further development the body becomes deeper, head smaller, and proportions are more like the adult. Tiny chromatophores increase greatly in number from dorsal aspect to lateral line, and the ventral half of body is noticeably light-colored with pigment spots sparsely distributed. At 53 millimeters the anal is speckled with black.

53.0-millimeter stage.—Total length, 53.0; standard length, 47.0; length to vent, 35.0; length of head, 11.8; greatest depth, 11.25; diameter of eye, 3.75 millimeters.

68.0-millimeter stage.—Total length, 68.0; standard length, 58.0; length to vent, 43.5; length of head, 14.5; depth at origin of dorsal, 13.15; diameter of eye, 4.0; length to origin of dorsal, 28.0 millimeters.

83.0-millimeter stage.—Yearling. Total length, 83.0; standard length, 70.5; length of head, 18.5; depth of head, 11.5; length to dorsal, 35.5; greatest length of dorsal rays, 14.25; depth at dorsal, 15.0; length to ventrals, 36.5; greatest length of ventral rays, 12.0; length to vent, 52.2; greatest length of anal rays, 9.5; length to pectorals, 17.5; greatest length of pectoral rays, 12.0; length of maxillary, 7.0;

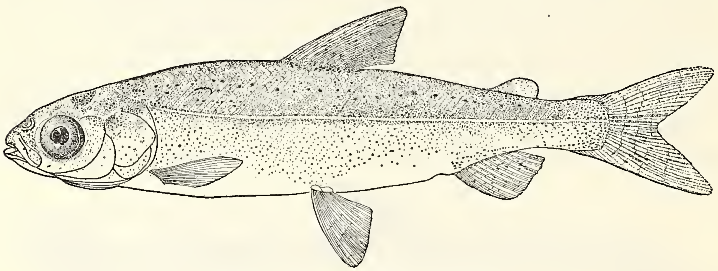

FIGURE 15.—*Coregonus clupeaformis*, 68 millimeters

interorbital width, 6.0; diameter of eye, 5.7 millimeters. Body fully scaled as in the adult.

Pigmentation.—The yearling whitefish is greenish gray above, very silvery on sides and below, with an area of light amber extending from just behind pectorals to lateral line. The eye is blue, edged in black.

The larval stages of *Coregonus clupeaformis* and *Leucichthys artedi* are easily confused, and the very small number of herring obtainable prevented us from formulating any rules of identification. It will be necessary to study many more specimens before we can be sure that the differences noted herein are constant.

I have pointed out a few outstanding characters in the above descriptions, especially the diffusion of yellow color in the whitefish throughout the yolk region, head, and sometimes over the whole body, as contrasted in the herring with the restriction of this pigment to the yolk sac. Furthermore, the double dorsal series of chromatophores in the whitefish is symmetrical, even, and continuous from behind head to tip of tail, while in the herring it becomes broken and uneven from shortly behind head often to a point more than halfway to vent. Although this character is certainly a valuable indication of the species, it can not be depended upon, for in our large collection of whitefish there were many in which the dorsal series was thin and sometimes quite uneven in this region, while among the dozen hatchery specimens

of young herring studied, one had a perfectly continuous line indistinguishable from that of the whitefish. In all our herring specimens the pigment over the intestine was very much less noticeable than in the whitefish.

In the specimens studied, the body of the whitefish was deeper than that of a herring of like size, and usually the latter species was somewhat more advanced in development at the same length. The more elongate body of the herring may be found to be a constant factor when the two species are reared together, subjected to the same temperature and environmental conditions, but only when this is done can complete faith be placed in proportional differences, so great is individual variation within the species. As an example, may I quote Ada Hall (1925) concerning the whitefish: "Fry hatching at 1, 2, and 4 months after spawning differ in size of body but not in size of yolk; those hatching at 4 months are 4 to 6 millimeters longer than those hatching earlier."

With the large number of hatchery herring promised for future study we hope to sift out of the present possibilities whatever differences are constant.

BREEDING

The whitefish spawns in November and early December, as does the herring, the eggs hatching the following spring. The period of incubation is dependent upon temperature.

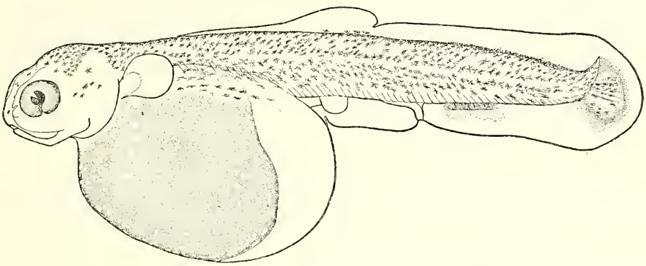

FIGURE 16.—*Cristivomer namaycush namaycush*, 16 millimeters

Family SALMONIDÆ, Trouts

5. Cristivomer namaycush namaycush (Walbaum). Lake trout. [*Cristivomer namaycush* (Walbaum). Jordan, Evermann, Clark, p. 59.]

RECORD OF CAPTURE

None of these uncommon fishes was taken by the *Shearwater* in 1928 and 1929, but eggs and newly hatched larvæ were supplied for study by the Cape Vincent hatchery. The species is restricted to the deeper parts of the lake where it is taken rarely by gill nets.

DESCRIPTION

Newly hatched larva, 16.0-millimeter stage.—Total length, 16; standard length, 14.78; length to vent, 10.3; length of head, 3.0; snout, 0.5; greatest depth before vent, 5.6; greatest depth behind vent, 2.9; diameter of eye, 1.1 millimeters. Myomeres, 42 to vent plus 20+ behind. Characterized by exceptionally large yolk sac,

large mouth, and many myomeres. The appearance of ventrals, elements of the anal, and turned-up notochord are characters rarely found in such an early larva. Dorsal marginal fin fold raised and notched over the middle of body, indicating the position of dorsal fin; adipose not marked out; a few caudal rays forming, but otherwise no rays discernible.

Pigmentation.—Only a few chromatophores are apparent on snout and sides of head, but many large, stellate spots cover top of head, and the dorsal and lateral aspects of body.

21.5-millimeter stage.—Total length, 21.5; standard length, 18.5; length to vent, 13.8; length of head, 4.3; snout, 0.85; diameter of eye, 1.4; greatest depth before vent, 4.8; greatest depth behind vent, 4.0 millimeters. Myomeres, 42 to vent plus 22 behind. The yolk sac much reduced from the preceding stage, but still of considerable size. About 8 rays in dorsal, 9 in anal, and most of the caudal rays visible.

BREEDING

Spawning takes place on rocky shoals and reefs in depths of 77 to 90 feet during October and November. The eggs develop on the bottom of rocky caverns over

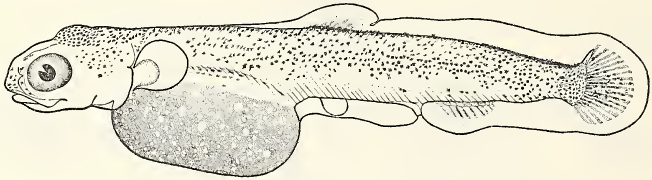

FIGURE 17.—*Cristivomer namaycush namaycush*, 21.5 millimeters

which they are deposited, and hatch in late winter or early spring. At a temperature of 47° F. in the laboratory, the larvæ hatch about the last week of January, but lower temperatures will retard incubation greatly. It is estimated that a 24-pound lake trout may spawn approximately 15,000 eggs.

6. Carpiodes cyprinus (LeSueur). White carp; buffalo mullet; quillback; swordfin.

RECORD OF CAPTURE

No larvæ of this species were taken by townets in Lake Erie, but adults were found commonly in the lake and in most of the larger streams of the region, and young were numerous at the mouths of creeks and on shallow mud flats several miles upstream.

DESCRIPTION

The young quillback resembles the carp (*Cyprinus carpio*) in its elongate dorsal fin, but is readily distinguished by the character of the small inferior mouth, small eye, and relatively long deep cheek. The difference in myomere counts is diagnostic (a 21 millimeter *C. cyprinus* has 25 plus 12+, and a *C. carpio* of equal length 19 plus 15–17 myomeres.)

21.0-millimeter stage.—Total length, 21.0; standard length, 16.5; length to vent, 13.4; length of head, 5.5; snout, 1.25; greatest depth before vent, 4.68; greatest depth

behind vent, 2.5; diameter of eye, 1.5; length to dorsal, 9.0; length to anal, 13.5 millimeters. Myomeres, 25 to vent plus 12+ behind. Dorsal I (very weak), 27; anal I (very weak), 7; ventrals 10, short; caudal forked; pectorals short, low. The falcate dorsal fin well formed, but its anterior rays are not as greatly produced as in the adult. Body oblong, with ventral outline nearly straight and dorsal slightly arched; mouth inferior, small, and horizontal; snout beginning to be pointed at this stage. Air bladder two-chambered.

Pigmentation.—Chromatophores are sparsely distributed on upper jaw, sides and top of head, more numerous over brain region and dorso-lateral aspects of body. A single row of larger spots lies along the dorsal ridge to caudal. Below lateral line chromatophores are scattered more widely. Double series on either side of anal fin is continued to caudal (unfortunately not well shown in specimen, fig. 22). Dorsal

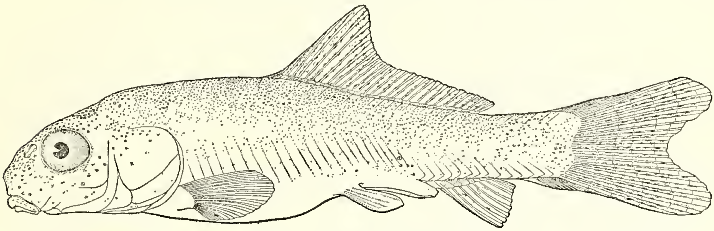

FIGURE 18.—*Carpiodes cyprinus*, 21 millimeters

and caudal are well marked with pigment, but other fins have few chromatophores or none.

Family CATOSTOMIDÆ, Suckers

7. Catostomus commersonii (Lacépède). Common sucker; white sucker; mullet.

RECORD OF CAPTURE

Numerous young, 15 to 25 millimeters long, were taken abundantly in shallow water at the eastern end of Lake Erie by meter nets, dip nets, and seines from the middle of June to the middle of July, 1928. None was taken by the *Shearwater* in 1929, probably because less work was done far inshore during this period. This species is one of the most common and widely distributed in the Lake.

DESCRIPTION

The very long intestine (myomeres, 33 to vent plus 10 behind) differentiates the young suckers at all stages from other species taken by the survey.

Egg.—The unfertilized egg measures 2.5 to 2.82 millimeters in diameter, being round, white, without oil globules, and finely granulate in texture. After fertilization, which occurs a few moments after extrusion, the egg measures 3 millimeters and the vitellus 2.5 millimeters.

The embryology and development have been thoroughly reported upon by N. H. Stewart (1926). It will suffice here to record the measurements and descriptions of two stages during the period of greatest change.

13.75-millimeter stage.—Total length, 13.75; length to vent, 13.0; greatest depth, 1.6; diameter of eye, 1.1; myomeres, 33 to vent plus 10+ behind. Head characterized by terminal, "horseshoe-shaped" mouth, and very large eye. Dorsal marginal fin fold very narrow, the later position of true dorsal indicated by a slight rise; ventral marginal very wide, extending forward almost to base of pectoral; caudal lophocercal with few rays apparent; no ventrals.

Pigmentation.—Body is colorless except for silver eyes edged in black, and black chromatophores distributed in four definite bands: (1) Group of stellate chromato-

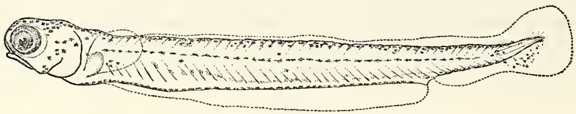

FIGURE 19.—*Catostomus commersonii*, 13.75 millimeters

phores on top of head followed by a triple line along dorsal ridge to end of body; (2) series of linear chromatophores along mid-lateral line of myomeres, about 56 from behind head to end of tail; (3) series starting behind head, congregated over dorsal surface of air bladder and continuing in massed line (about 4 chromatophores wide) to vent, mostly subsurface; and (4) series of about 57–60 large round and stellate pigment spots along ventral ridge from behind head to vent, thence as a massed line of about 4 chromatophores wide to end of body. Caudal fin fold is peppered with very small chromatophores near its base.

14.2-millimeter stage.—Total length, 14.2 standard length, 12.9; length to vent, 10.1; length of head, 2.75; greatest depth, 2.2; diameter of eye, 1.0 millimeters.

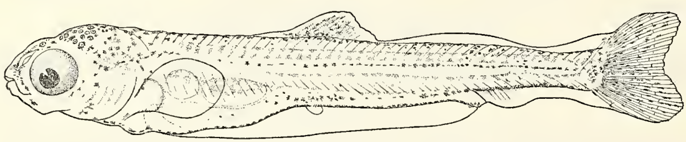

FIGURE 20.—*Catostomus commersonii*, 14.2 millimeters

Myomeres, 33 to vent plus 10+ behind. Snout less blunt; air bladder two-chambered. Dorsal fin developed with evidences of 10 rays, and suggestion of about 4 anal rays; ventrals developing; caudal heterocercal; embryonic marginal fin fold persisting behind dorsal and complete on ventral aspect.

Pigmentation.—The pigmentation here is essentially as in the previous stage, with the addition of more chromatophores in the caudal, and a few stellate ones in dorsal fin. The extreme transparency of a living specimen reveals many subsurface chromatophores: One series above and another below the nerve chord, connected laterally at intervals corresponding to the myomere interspaces, and a third series marking the ventral aspect of the notochord. Gill arches are likewise margined with subsurface chromatophores.

20.5-millimeter stage.—Dorsal and anal fins complete.

BREEDING

The white sucker spawns in shallow water in April or May, soon after the ice leaves. It's spawning behavior has been thoroughly recorded by J. E. Reighard (1920).

8. Hypentelium nigricans (Le Sueur). Hammerhead; stone-roller sucker; hog sucker.

RECORD OF CAPTURE

This species was taken along the shores of Lake Erie near stream mouths but more commonly in the larger shallow and warm creeks.

DESCRIPTION

The head of the stone-roller differs from other suckers in its flattened contour with interorbital space concave and orbital rims broadly elevated.

21.0 millimeter stage.—Total length, 21.0; standard length, 18.0; length to vent, 13.0; length of head, 5.1; snout, 1.35; diameter of eye, 1.35; greatest depth before

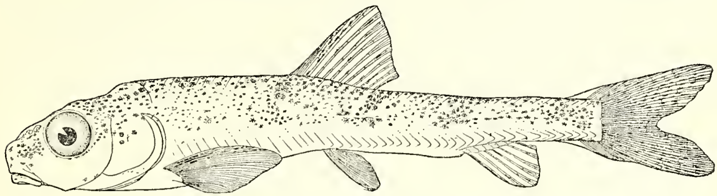

FIGURE 21.—*Hypentelium nigricans*, 21 millimeters

vent, 3.3; greatest depth behind vent, 1.6; length to dorsal, 8.5; to anal, 13.5 millimeters. Myomeres, 30 to vent plus 14–15 behind. Dorsal II (very weak), 11; anal, 7; ventrals, 9; caudal deeply forked; all fins large. Lips large, strongly papillose, wide inferior mouth; eye rather small, near middle of head. Resembles *Catostomus commersonii* in rather short dorsal fin and 2-chambered air bladder, but differs in having head concave above, scales fewer than 48 (60 in the common sucker), and oblique cross bars on body instead of plain or blotched color.

Pigmentation.—Chromatophores appear over snout, upper lip, and top of head, large stellate ones on dorsal aspect to caudal, and smaller ones to below lateral line. Through this upper pigmented region oblique pigment bars pass to below lateral line: 1 behind head, 1 at origin of dorsal, 1 at posterior end of dorsal, another halfway between dorsal and caudal, and the last one at caudal base. The belly is white (differing from *Catostomus* in which there is a prominent ventral line series). Chromatophores are distributed on dorsal, caudal, and pectorals; ventrals and anal are colorless.

BREEDING

The stone-roller sucker is a spring spawner, and the young are found abundantly in small creeks and rivers.

9. Moxostoma aureolum (Le Sueur). Red-fin mullet; red-horse sucker.

RECORD OF CAPTURE

Only one specimen was taken each year by the *Shearwater*, the first at the mouth of Beaver Creek on July 11, 1928, in a meter net at 6 meters below the surface, and the second near Angola on August 6, 1929, at the surface in water of 11 meters. Although mostly an inhabitant of large streams, it is moderately common in Lake Erie.

DESCRIPTION

The red-fin mullet larva suggests that of *C. commersonii* in general characters but is readily distinguished by the foreshortening of the body before the vent, myomeres numbering only 24 plus 13 while in the common white sucker there are 33 plus 10.

7.5-millimeter stage.—Total length, 7.5; standard length, 7.1; length to vent, 5.0; greatest depth, 1.2; diameter of eye, 0.5. Myomeres, 24 to vent plus 13 behind. Low dorsal embryonic marginal fin fold originating over tenth myomere behind head and a slight cell concentration at its beginning indicating the later location of true dorsal; ventral marginal originating in advance of dorsal and much deeper anteriorly,

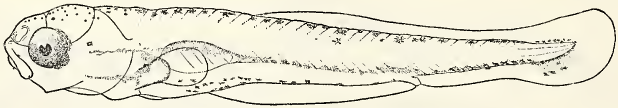

FIGURE 22.—*Moxostoma aureolum*, 7.5 millimeters

identical with dorsal behind vent; pectorals moderate, extending more than halfway to posterior margin of air bladder; caudal lophocercal. Mouth moderate, terminal, upper jaw somewhat projecting, suckerlike; eye moderate; snout almost as long as eye; interorbital space wide; air bladder large, one-chambered at this young stage.

Pigmentation.—Small black chromatophores are evenly distributed over head, followed by a double uneven line of very large stellate ones widely separated from each other on dorsal aspect, numbering about 26–35. From midline of eye backward there appears a subsurface series of many black chromatophores crowded into a continuous line on either side of head, merging into a large black patch over top of air bladder, then continuing along dorsal aspect of intestine to vent and beyond along underside of tail almost to caudal. On underside of stomach region is a very unequal double series sparsely distributed to about middle of intestine, and a few more near the vent. A double line of small chromatophores appears on ventral aspect from vent to caudal, but there are very few chromatophores on the caudal itself. On ventral aspect, subsurface chromatophores are similar to those on sides of head, starting behind eye and extending backward to meet those at anterior margin of air bladder.

The specimen immediately suggests the young of *Catostomidæ* in general characters. It differs, however, from *C. commersonii* in several respects, especially in a myomere count of only 37 contrasted with 43 or more in the latter species. The foreshortening occurs before the vent, having only 24 myomeres in this region while the common sucker has 33–35. The indications are that the dorsal fin will be short and

median and the eye near the middle of the head. Constriction of air bladder has not begun, and it is therefore impossible to use that character for identification purposes.

It is undoubtedly a species of *Moxostoma*, this being the only genus of suckers beside *Catostomus* which is abundant in the region. *M. anisurum*, *M. aureolum*, and *M. lesuerii* were taken here in the same summer. The head is rather long for the last species, which is especially short-headed. The myomere count of a specimen of *M. anisurum* taken near by was 30 plus 13. Because the myomere count of *M. aureolum* is identical, our specimen probably can be attributed to that species.

10. Moxostoma anisurum (Rafinesque). White-nosed red-fin mullet; red-horse sucker.

RECORD OF CAPTURE

Young of this species were found generally at creek mouths during the summers of 1928 and 1929. It is a common species of Lake Erie, Niagara River, and large tributaries.

DESCRIPTION

The 3-chambered air bladder, evident at 19.5 millimeters, and scales in fewer than 50 rows distinguish larvæ of this genus from other suckers, and the dorsal ray count of 14 to 17 identifies *M. anisurum* from other species of *Moxostoma* taken locally.

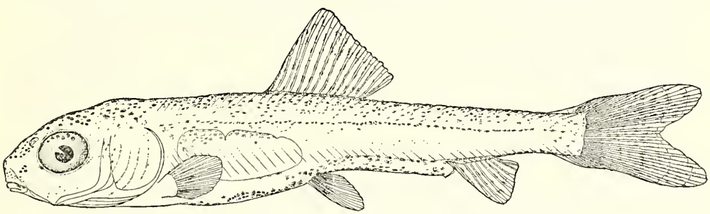

FIGURE 23.—*Moxostoma anisurum*, 19.5 millimeters

19.5-millimeter stage.—Total length, 19.5; standard length, 16.0; length to vent, 12.2; head, 4.5; snout, 1.1; eye, 1.3; greatest depth before vent, 3.0; greatest depth behind vent, 1.55; length to dorsal, 7.5; length to anal, 12.5 millimeters. Myomeres, 29 to vent plus 14 behind. Dorsal 15; anal 8 (with 1 very weak unsegmented ray before); caudal slender, deeply forked. The young white-nosed red-fin mullet strongly resembles the common red-fin mullet (*M. aureolum*), but the great difference in myomere count readily identifies the two. Snout abruptly decurved, mouth wholly inferior, lower jaw included, lower lip with sides widely conjoined. Third chamber of air bladder forming at this stage.

Pigmentation.—Chromatophores are distributed over snout and top of head followed by a very dark double series on dorsal ridge. Smaller ones cover dorsolateral aspect, and the lateral line is well marked by a single series. Subsurface spots appear outlining gills, over air bladder, and dorsal surface of intestine. There is a ventral irregular series from behind pectorals to vent, thence a double row to caudal. Pectorals and ventrals have few pigment spots, but dorsal, anal, and caudal are well covered.

BREEDING

Like *M. aureolum*, this species runs upstream to spawn, the run being coincident with the leaving of the ice.

Family CYPRINIDÆ, Minnows

11. Cyprinus carpio Linnaeus. Carp, German carp.

RECORD OF CAPTURE

A number of larvæ and young adults of this species were taken in a dip net off Crescent Beach on June 29, 1929. The carp is very abundant and widely distributed throughout the Lake Erie region in nearly all waters except the small rapid creeks. A native of Asia, but introduced into America for pond culture, it is now one of the commonest species of Lake Erie.

DESCRIPTION

The early larva is easily recognized by its comparatively large size, 9 to 10 millimeters, and heavy black pigmentation, and in the postlarval stages by its long

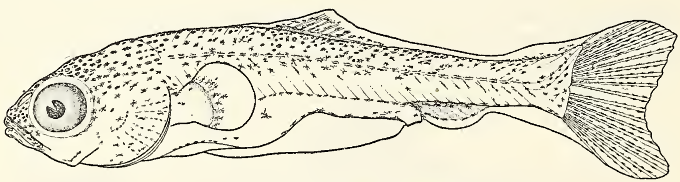

FIGURE 24.—*Cyprinus carpio*, 10 millimeters

dorsal (III, 20) and short anal (III, 5), and the appearance of two barbels on either side of upper jaw. Although the quillback, *C. cyprinus*, has a similarly long dorsal, the large terminal mouth, large eye, and comparatively short cheek of the carp will prevent any confusion. A myomere count of 19 plus 15–17 in the young carp, and 25 plus 12 + in the quillback differentiates them further.

10.0-millimeter stage.—Total length, 10.0; standard length, 8.4; length to vent, 6.4; length of head, 2.5; snout, 0.46; diameter of eye, 0.8; greatest depth before vent, 1.9 millimeters. Myomeres, 18 to vent plus 12 behind. Body stout; head rather small; moderate mouth extending slightly past front of large eye at this stage. Rounded pectorals unrayed; dorsal showing about 10 elements and 6 rays developed; anal elements and rays evident; caudal forked, rays formed; no ventrals apparent.

Pigmentation.—Both jaws, top of head, and dorsal aspect are covered by large stellate chromatophores. Pigment spots are fewer on sides of head and body to lateral line. Lateral line is marked by a double subsurface series, and subsurface chromatophores appear also on gills and on dorsal surface of intestines. There is a broken double ventral series to vent, heavier on ridge behind vent to caudal. All fins are marked with chromatophores.

13.3-millimeter stage.—Total length, 13.3; standard length, 11.1; length to vent, 8.52; length of head, 3.7; snout, 1.1; diameter of eye, 1.0; greatest depth before vent, 2.75 millimeters. Myomeres, 21 (22) to vent plus 13 behind. Differing from pre-

ceding stage principally in further development of dorsal and anal, appearance of ventrals, and heavier pigmentation.

30.75-millimeter stage.—Total length, 30.75; standard length, 25.0; length to vent, 19.5; length of head, 8.5; greatest depth, 8.5; diameter of eye, 2.6 millimeters. Myomeres, 19 to vent plus 17 behind. Dorsal III, 20; anal III, 5. Characterized by a strong serrated spine at beginning of dorsal and anal, and a barbel on either side of upper jaw (2 in adult), distinguishing it from *Carassius auratus* which has no barbels. Body stout, mouth moderate.

Pigmentation.—Chromatophores are thickly massed on upper lip and top of head spreading over snout and below eye. Dorsal edge of iris is speckled. Heavy pigment spots occur on dark background over head and along dorsal aspect to dorsal fin. Chromatophores are heavily distributed to lateral line, scarcer below. Ventral aspect is unmarked except for a few chromatophores near vent and a subsurface series from vent to caudal. All fins, with the exception of ventrals, are marked.

BREEDING

The spawning season of the carp lasts from June until August. They are very prolific and grow rapidly. T. H. Bean (1903) states:

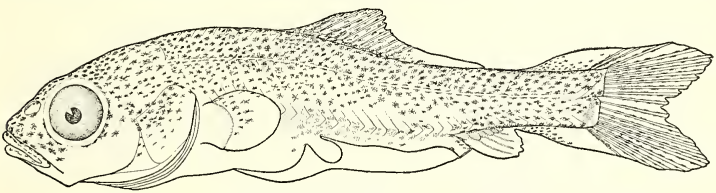

FIGURE 25.—*Cyprinus carpio*, 13.3 millimeters

> During the spawning the fish frequently rise to the surface, the female accompanied by two or three males. The female drops the eggs at intervals during a period of some days or weeks in shallow water on aquatic plants. The eggs adhere in lumps to plants, twigs, and stones. The hatching period varies from 12 to 16 days.

12. **Nocomis micropogon** (Cope). Crested chub, river chub.

RECORD OF CAPTURE

The crested chub was not found in Lake Erie, but was taken commonly by the survey in the warmer tributary streams.

DESCRIPTION

Young fishes of this species are distinguished from the allied genus *Notropis* by the presence of a maxillary barbel. They resemble closely, also, *Semotilus atromaculatus* but differ in the position of this barbel which has its origin at tip of maxillary rather than well in advance of tip.

22.0-millimeter stage.—Total length, 22.0; standard length, 18.0; length to vent, 11.6; length of head, 5.25; snout, 1.25; diameter of eye, 1.6; greatest depth before vent, 4.1; greatest depth behind vent, 3.0; length to dorsal, 11.5; to anal, 12.1 millimeters. Myomeres, 22 to vent plus 15–16 behind. Dorsal III (very weak), 7; anal

II (very weak), 7; ventrals just posterior to front of dorsal. Body scaled at this stage, with abdomen rounded and scaled (scales on lower half of body not shown in fig. 26); scales large, 6–40 to 45–5. Body rather short and stout; mouth large and low; upper jaw almost terminal; conical snout of later stages barely perceptible; preorbital wider than eye; small barbel apparent at tip of maxillary.

Pigmentation.—The young crested chub is white with dorsal aspect of head covered by round black chromatophores. Small, even spots occur on dorsal aspect of body to vent with a double row of larger ones along dorsal ridge. Dorso-lateral aspect has small chromatophores arranged along margins of scales. A heavy lateral stripe extends from tip of snout to base of caudal, forming a darker caudal spot. There are a few chromatophores in ventro-lateral region of tail and around anal, but otherwise the ventral aspect is unpigmented. All fins except ventrals are marked, the pectorals most sparingly. The brilliant colors of the adult are not yet evident.

BREEDING

The name of crested chub arises from the character of the head of the breeding male, for it is swollen into a crest and covered by tubercles. Often a red spot appears

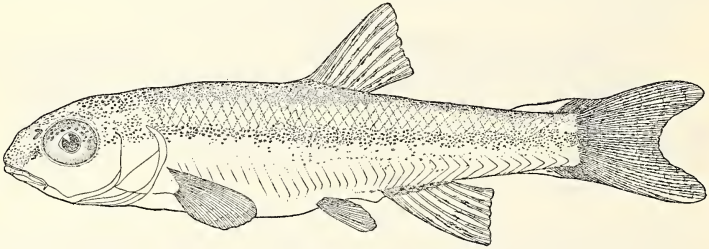

FIGURE 26.—*Nocomis micropogon*, 22 millimeters

on either side of the head. John Greeley (1929) observed a breeding male guarding its nest on July 9, 1928, in Silver Creek, at a temperature of 83° F. The nest was built of pebbles which had been painstakingly picked up and put into place separately. The male chub spawned with each of several females, and after each spawning act piled more stones upon the nest to cover the eggs. After preservation in formalin these eggs measured 2 millimeters in diameter.

13. Erinemus storerianus (Kirtland). Storer's chub.

RECORD OF CAPTURE

Larval stages up to 7.5 millimeters were taken from Buffalo to Rondeau during the latter half of June and the first week of July, usually in bottom hauls in water of from 18 to 20 meters depth. At the western end of the lake in 1929 early larval stages were taken commonly from June 7 until July 2, being most abundant on the latter date. Storer's chub is a common species in the Lake Erie region alongshore, at creek mouths, and ranging out into comparatively deep water.

DESCRIPTION

The earliest larvæ are characterized by a very prominent, overhanging snout, and elongate clear yellow yolk sac with one large oil globule anteriorly placed. In later stages the slightly inferior mouth, very elongate body, and short head with wide interorbital are diagnostic. Myomere count of 19 plus 17, as well as head differences and pigmentation, distinguish the young from those of the equally elongate *N. atherinoides.* (Myomere count of latter, 23 plus 12–13.)

5.0-millimeter stage.—Total length, 5.0; length to vent, 2.6; length of head, 0.73; snout, 0.25; diameter of eye, 0.25; greatest depth before vent, 0.75; greatest depth

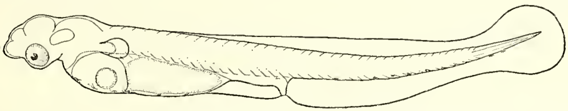

FIGURE 27.—*Erinemus storerianus,* 5 millimeters

behind vent, 0.76 millimeter. Myomeres, 18 before vent plus 21 behind. Characterized by extremely delicate, slender body, clear yellow elongate yolk sac with one large oil globule located anteriorly, rather small eye placed low, dorsal marginal fin fold low, originating shortly before vent, continuous around lophocercal caudal and forward past vent to yolk sac, much wider ventrally, and the very long, overhanging snout without mouth opened.

The newly hatched specimens differ markedly from those of *N. atherinoides* in having the eye fully pigmented, a much shorter intestine, and deeper yolk sac of clear yellow with a large oil globule in anterior region. The sparsely distributed ventral chromatophores behind the vent and on the stomach are characteristic. The size

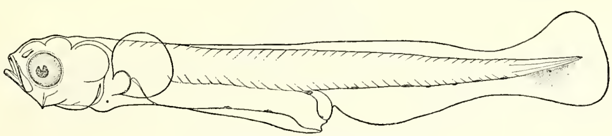

FIGURE 28.—*Erinemus storerianus,* 7 millimeters

is about as in *N. atherinoides,* but these specimens are somewhat slenderer even than that elongate species.

Pigmentation.—Two irregular lines of stellate chromatophores are evident on underside of yolk region, a pair on either side of body where intestine bends downward to vent, and a single series of about 12 small ones on ventral margin, farther apart forward but smaller and near together toward caudal region. In further development these ventral line chromatophores become further embedded below the surface and less conspicuous for this reason.

7.0-millimeter stage.—Total length, 7.0; length to vent, 3.9; length of head, 1.25; snout, 0.23; diameter of eye, 0.38; greatest depth before vent, 1.08; greatest depth behind vent, 1.0 millimeter. Myomeres, 18 to vent plus 21 behind.

Pigmentation.—One chromatophore appears at ventral base of each pectoral, 2 small chromatophores on ventral aspect of intestine, 1 where intestine turns down-

ward to vent, 6 in a single series on ventral ridge of tail (less conspicuous than in 5-millimeter stage), and 1 on caudal. The eye is black.

These specimens are definitely unlike any other species previously taken by the survey, and their small size and lack of any adult characters make the determination extremely difficult. In this, as in similar cases, it is necessary to resort to a process of elimination, narrowing down the possibilities as far as possible and then temporarily choosing one. No young stages of Storer's chub have been described, and since the

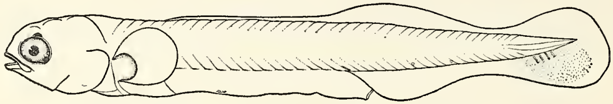

FIGURE 29.—*Erinemus storerianus*, 9.5 millimeters

smallest known specimen available is 21 millimeters, we are unable to tell what the larva may be like. Certain facts, however, suggest this species: (1) Such characters as the elongate body and slender caudal peduncle, rather short head with broad interorbital, large eye placed high, moderate horizontal mouth with lower jaw included, and prominent snout; (2) the great abundance of Storer's chub in Lake Erie. The identification of these specimens as *E. storerianus* must, therefore, be subject to change.

9.5-millimeter stage.—Total length, 9.5; standard length, 9.1; length to vent, 5.7; length of head, 2.0; diameter of eye, 0.5; greatest depth before vent, 1.2; depth behind vent, 0.75 millimeter. Myomeres, 19 to vent plus 19 + behind. Body more robust

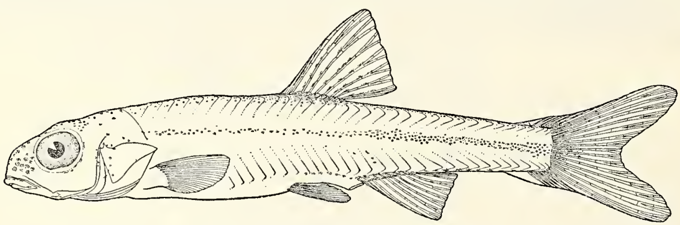

FIGURE 30.—*Erinemus storerianus*, 21 millimeters

than preceding stage but otherwise unchanged. Ray development beginning ventrally at lophocercal caudal.

Pigmentation.—On the surface, 1 chromatophore is apparent at middle of ventral aspect of intestine and below the surface, 1 occurs at ventral edge of body where intestine turns downward to vent, and 2 along middle third of tail. (More of these ventral subsurface spots on tail are evident in other specimens, resembling more closely the prominent series of the 5-millimeter stage which has become almost hidden in larger preserved specimens.)

21.0-millimeter stage.—Total length, 21.0; standard length, 17.0; length to vent, 11.0; length of head, 4.5; snout, 1.2; diameter of eye, 1.4; greatest depth before vent, 3.35; greatest depth behind vent, 2.2; length to dorsal, 9.0; to anal, 11.5. Myomeres, 19 to vent plus 17 + behind. Dorsal II (very weak), 8; anal II (very weak), 8;

pectorals pointed; caudal long and deeply forked; ventrals inserted behind dorsal origin, not quite reaching vent. Characterized by elongate body; short compressed head with cheeks vertical and rather flat interorbital space; eye very large, high, entirely above premaxillary; mouth small, not reaching orbit, horizontal, lower jaw included; snout very abruptly decurved; preorbital bone conspicuous, rather oblong; no scales at this stage.

Pigmentation.—Black chromatophores occur over upper jaw, top, and sides of heads, and two rows along either side of dorsal ridge from behind head to caudal. Three or four rows of very small spots mark the lateral line, but no dark lateral stripe is apparent as in some other cyprinids. There are a few subsurface chromatophores on dorsal surface of intestine near vent, and a double series from vent to caudal on ventral ridge. Heavy chromatophore marking shows at base of dorsal and anal, and the dorsal and caudal fins are marked.

BREEDING

From the present collections it is evident that Storer's chub spawns during June and the first week of July, for all specimens taken throughout this period were in early stages of development.

14. Rhinichthys atronasus lunatus (Cope). Black-nosed dace. [*Rhinichthys lunatus* Cope. Jordan, Evermann, Clark, p. 140.]

RECORD OF CAPTURE

Although this species strays only rarely into Lake Erie, it may be found in great numbers in all small creeks of the region.

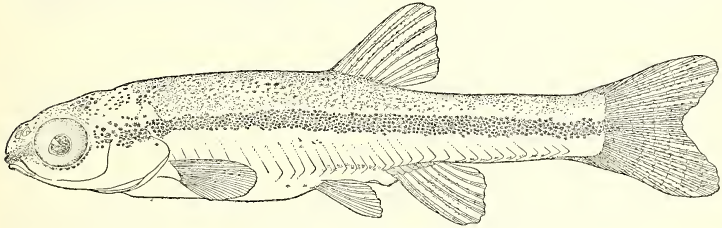

FIGURE 31.—*Rhinichthys atronasus lunatus*, 17.25 millimeters

DESCRIPTION

The black-nosed dace is easily distinguished from the closely allied long-nosed dace (*R. cataractæ*) by the facts that in the former the snout scarcely projects beyond the slightly oblique mouth, and the broad lateral band extends on to caudal.

17.25-millimeter stage.—Total length, 17.25; standard length, 14.25; length to vent, 9.5; length of head, 4.0; snout, 0.75; diameter of eye, 1.3; greatest depth before vent, 3.1; greatest depth behind vent, 2.0; length to dorsal, 8.2; to anal, 9.6 millimeters. Myomeres, 18 to vent plus 17+ behind. Dorsal II (rudimentary), 7 (with last divided at base in transparent specimen, appearing thus as an eighth ray), inserted behind middle of standard length; anal II (rudimentary), 6. Moderately elongate body; mouth small and slightly oblique; snout barely protruding.

Pigmentation.—A broad band of black chromatophores extends from tip of snout to end of body, terminating in a black spot at base of caudal and extending out on to fin. The head and dorsal aspect of body are covered with small chromatophores extending down to meet the lateral band (not so in *R. cataractæ*). Subsurface chromatophores are heavy on dorsal aspect of intestine and a double series (4 chromatophores wide around anal base) occurs on ventral ridge. All fins are marked. No black is evident on lower lip as in *Semotilus atromaculatus.*

BREEDING

The black-nosed dace is a spring spawner, seeking the upper courses of streams over clean gravel. During the breeding season the males have the lateral band, lower fins, and sometimes the whole body colored bright crimson.

15. Rhinichthys cataractæ (Cuvier and Valenciennes). Long-nosed dace.

RECORD OF CAPTURE

One young 18.5-millimeter specimen was taken at the mouth of Eighteen Mile Creek on July 18, 1928, and another 12.5 millimeters long on June 29, 1929, in a foot

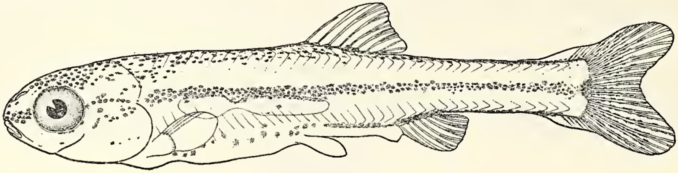

FIGURE 32.—*Rhinichthys cataractæ*, 13.7 millimeters

net towed in 3 feet of water off Crystal Beach. Adults are very common along the lake shore, especially over rocky bottom and in the lower courses of nearly all streams of the region, but this species does not seek the headwaters as does *atronasus.*

DESCRIPTION

The young are characterized by a dusky lateral band and caudal spot which does not extend out on to the fin as in *R. atronasus lunatus.* This band fades in the adult. The protruding snout of the later stages is evident even in these small specimens.

13.7-millimeter stage.—Total length, 13.7; standard length, 12.2; length to vent, 8.5; length of head, 3.1; diameter of eye, 1.0; snout, 0.85; greatest depth before vent, 2.3; depth behind vent, 1.6; length to dorsal, 6.3 millimeters. Myomeres, 22 to vent plus 15 behind. Dorsal I, 7; anal I, 6; ventrals well developed. Body elongate; mouth small, with protruding snout characteristic of later stages evident but not pronounced, lower jaw included.

Pigmentation.—This species is characterized by a dusky lateral band forming a small spot at base of caudal, but this is much fainter than in *R. atronasus*, *Semotilus atromaculatus*, and others. (Lateral band is obsolete in adult.) Chromatophores occur on top of head, along dorsal ridge, and ventral ridge from vent to caudal, and

subsurface chromatophores along dorsal surface of intestine. The lateral surfaces are colorless except for the faint dusky band (unlike *atronasus*). The caudal is the only fin pigmented.

BREEDING

The long-nosed dace is apparently a spring spawner. Breeding males have cheeks, lips, and lower fins bright crimson.

16. Semotilus atromaculatus atromaculatus (Mitchill). Horned dace, creek chub. [*Semotilus atromaculatus* (Mitchill). Jordan, Evermann, Clark, p. 117.]

RECORD OF CAPTURE

Although rarely taken from Lake Erie, the horned dace is common in all its tributaries, especially in the smaller creeks.

DESCRIPTION

Young horned dace are characterized by a very heavy black lateral band from tip of snout to base of caudal, where it widens into a well-defined black spot. Perito-

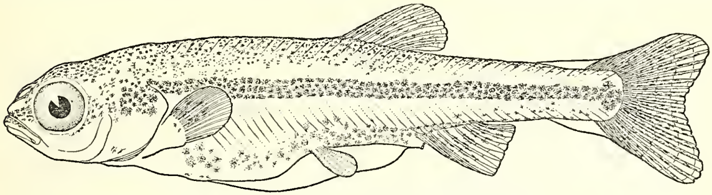

FIGURE 33.—*Semotilus atromaculatus atromaculatus*, 14 millimeters

neum typically pale, although in preserved specimens sometimes darkened, while in *Campostoma anomalum* it is always very black. The latter is easily confused with *Semotilus atromaculatus* in the younger stages, but if the specimens are large enough to have the lateral line, that of *Campostoma* will be found straight, while that of *Semotilus* dips abruptly over the first half of the pectoral. Of course, the peculiar elongate intestine of *Campostoma* surrounding the air bladder is always diagnostic, but its investigation necessitates dissection.

14.0-millimeter stage.—Total length, 14.0; standard length, 12.5; length to vent, 8.25; length of head, 3.4; diameter of eye, 1.1; greatest depth before vent, 2.8; depth behind vent, 1.7; length to dorsal, 7.0; to anal, 8.5 millimeters. Myomeres, 21 (or 22) to vent plus 20 behind. Fins small; dorsal II, 7, inserted well behind ventrals; anal I, 8 (incomplete?), completely behind dorsal. Forward part of body rather stout but tail compressed, moderately elongate head heavy, rounded above; mouth moderate, oblique, lower jaw included, maxillary to pupil.

Pigmentation.—Both jaws, top of head, and dorsal aspect are covered throughout with large and small chromatophores. A lateral black stripe extends from tip of snout to base of caudal, being composed of 3 lines of heavy spreading chromatophores. The lateral aspect below this band is colorless except for few chromatophores near caudal. A few occur on underside beneath the jaws, pectorals, and one row along either side of ventral line from vent to caudal. About 60 subsurface,

large, round chromatophores are evident over stomach region and intestine. Ventrals are unpigmented but other fins are marked with double series of pigment spots along sides of rays. The chromatophores are thicker on front of dorsal base, indicating later diagnostic dorsal spot.

BREEDING

The horned dace spawns in spring in stony shallow streams. Rosy-tinted belly and coarse tubercles on the snout constitute the breeding dress of the male.

17. Clinostomus elongatus (Kirtland). Red-sided dace.

RECORD OF CAPTURE

The red-sided dace was never taken in Lake Erie but was found frequenting many of its small tributary streams.

DESCRIPTION

This brilliant little species very closely resembles the abundant *Notropis*, but the teeth in main row numbering 5–5 distinguish it from the latter, which usually has 4–4.

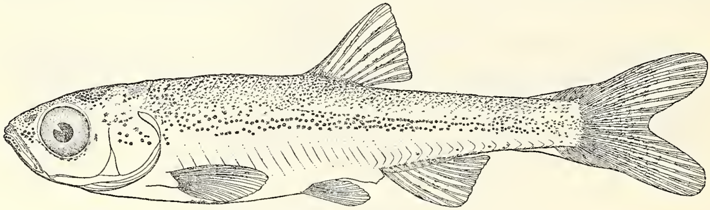

FIGURE 34.—*Clinostomus elongatus*, 23.25 millimeters

23.25-millimeter stage.—Total length, 23.25; standard length, 19.2; length to vent, 12.5; length of head, 5.7; snout, 1.25; diameter of eye, 1.6; greatest depth before vent, 4.2; depth behind vent, 2.6; length to dorsal, 10.1; to anal, 13 millimeters. Myomeres, 19 to vent plus 16 behind. Dorsal II (rudimentary), 8; anal I (rudimentary), 9; ventral origin very slightly in advance of first dorsal ray, ventrals reaching vent; caudal long and deeply forked. Body elongate, fusiform, with slender caudal peduncle; head large; snout long, pointed; mouth large, oblique, lower jaw barely projecting in this stage (projecting strongly in adult); lateral line abruptly decurved over anterior half of pectoral.

Pigmentation.—Both jaws, and dorsal aspect of head are heavily pigmented with round black spots. A band extends the length of dorsal aspect with chromatophores more loosely arranged to lateral line. Below lateral line the chromatophores are heavy again, forming a very inconspicuous band, about 4 chromatophores wide, from head to caudal. Ventrolateral and ventral aspects are without pigment except for about 4 chromatophores beneath abdomen and 4–6 on sides of ventral ridge from anal backward. Subsurface chromatophores occur on gill arches and stomach-intestinal region. Ventrals and pectorals are almost unmarked, but other fins have chromatophores along lines of rays.

BREEDING

This minnow, also, is a spring spawner, and the anterior part of the lateral band becomes bright crimson in breeding males.

18. Notropis heterolepis Eigenmann and Eigenmann. Black-nosed minnow. [*Hybopsis heterolepis* Eigenmann and Eigenmann. Jordan, Evermann, Clark, p. 134.]

RECORD OF CAPTURE

The black-nosed minnow seeks the quiet, sheltered bays of Lake Erie, and the muddy streams and swampy places near by.

DESCRIPTION

The absence of black on the chin readily distinguishes this species from the allied *N. bifrenatus* and *N. heterodon* in which the lateral band passes through the higher mouth, pigmenting both jaws.

20.0-millimeter stage.—Total length, 20.0; standard length, 16.6; length to vent, 11.0; length of head, 4.5; snout, 1.4; diameter of eye, 1.15; greatest depth before

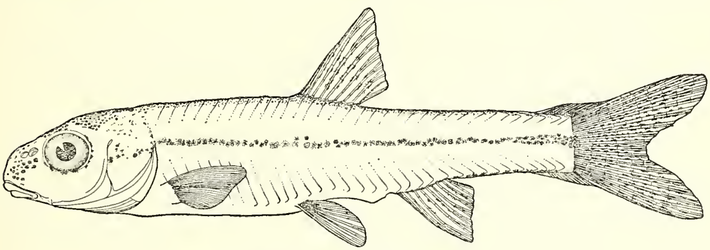

FIGURE 35.—*Notropis heterolepis*, 20 millimeters

vent, 3.3; depth behind vent, 2.4; length to dorsal, 9.1; to anal, 11.2 millimeters. Myomeres, 19 to vent plus 15 behind. Dorsal II (rudimentary), 8 (last divided), slightly nearer caudal than tip of snout; anal II (rudimentary), 8 (last divided); ventrals inserted in advance of dorsal. Body slender; snout longer than eye; mouth subinferior, small, nearly horizontal, lower jaw included.

Pigmentation.—The black-nosed minnow is generally less pigmented than other minnows at this length. Chromatophores are restricted to upper jaw, top and upper half of head, about 4 irregular lines along dorsal ridge to caudal, a single or irregular double series marking lateral line as a continuation of the band which starts at tip of snout, a very few below head and around anal base, and on dorsal, anal, and caudal fins. The white chin is diagnostic.

BREEDING

This species spawns in late spring and early summer. John Greeley (1929) found females in spawning condition on July 26, 1928, in the Niagara River.

19. Notropis deliciosus stramineus (Cope). Straw-colored minnow. [*Hybopsis deliciosa straminea* Cope. Jordan, Evermann, Clark, p. 134.]

RECORD OF CAPTURE

On July 28, 1928, eight small specimens ranging in size from 4.7 to 11.5 millimeters were taken near the mouth of Muddy Creek, and a 16.3-millimeter fish was seined at Long Point Bay on August 22. In 1929 none appeared in our collections until August 6; larvæ and postlarvæ were extremely abundant from Angola to Port Dover in the eastern and about Point Pelee in the western parts of the lake for the next 2 weeks, as many as 85 having been taken in a 5-minute haul at station 06.47. They were found on the bottom as well as at the surface in water of 11 to 34 meters. Adults are found abundantly, especially during late June and early July when they come close inshore for spawning.

DESCRIPTION

The smallest larva is distinguished from the closely related *N. atherinoides* by its shorter, heavier body, pigmented eye, and chromatophore series above and below the intestine and along ventral ridge, and by the location of the vent at the nineteenth

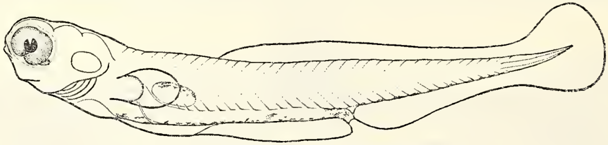

FIGURE 36.—*Notropis deliciosus stramineus*, 5 millimeters

myomere (at twenty-third or twenty-fourth in *N. atherinoides*). In advance stages of development the pigment patterns of the two species become much alike, but the deeper head and body, the different myomere count (19 or 20 to vent plus 16 behind in the present species; 23 to vent plus 12 or 13 behind in *N. atherinoides*), and the insertion of the ventrals in *N. deliciosus stramineus* only 1 myomere before the beginning of dorsal fin (about 4 myomeres distant in *N. atherinoides*) serve to differentiate them, even though the young of both species may be found together.

5.0-millimeter stage.—Total length, 5.0; length to vent, 3.0; length of head, 0.9; snout, 0.05; diameter of eye, 0.35; greatest depth before vent, 0.08; depth behind vent, 0.07 millimeter. Myomeres, 19 (20) to vent plus 16 behind. Yolk sac absorbed; single air bladder; head remarkably broad, broader than deep; snout short, very obtuse; tail lophocercal.

Pigmentation.—The eye is black. Dorsal aspect of air bladder is very dark, and subsurface chromatophores occur above intestine to vent. There are many chromatophores on ventral surface of stomach region, continuing as a very uneven double series to vent. A few appear on ventral ridge behind vent.

6.5-millimeter stage.—Chromatophores larger and arranged in more regular series above and below intestine, and on ventral ridge behind vent. Head still broader than deep as in preceding stage. Slight concentration in marginal fin indicating position of dorsal.

7.5-millimeter stage.—Total length, 7.5; standard length, 7.05; length to vent, 4.7; length of head, 1.5; snout, 0.2; diameter of eye, 0.55; greatest depth before vent,

1.4; depth behind vent, 1.0 millimeter. Myomeres, 21 to vent plus 16 behind. Dorsal concentration increased and position of anal evident; notochord turning upward and some caudal rays developed.

Pigmentation.—A few large round chromatophores occur on top of head, and a broken double series on dorsal ridge. A lateral line series extends from above air bladder backward, and a ventral series from jugular region to caudal, becoming double behind vent.

12.0-millimeter stage.—Total length, 12.0; standard length, 9.5; length to vent, 7.0; length of head, 2.8; snout, 0.6; diameter of eye, 0.8; greatest depth before vent,

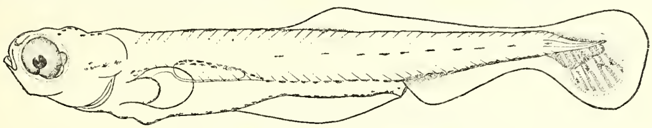

FIGURE 37.—*Notropis deliciosus stramineus,* 7.5 millimeters

2.0; depth behind vent, 1.2; length to dorsal, 5.5; to anal, 7.2 millimeters. Myomeres, 21 to vent plus 16 behind. Dorsal, 9; anal, 7; ventrals apparent immediately before first ray of dorsal (in *N. atherinoides* 4 myomeres before dorsal); caudal fully formed. Air bladder two chambered.

Pigmentation.—Chromatophores are arranged generally as in the preceding stage, but they are larger and more conspicious. Chromatophores occur also on caudal.

28.6-millimeter stage.—Dorsal, 9; anal, 8; caudal deeply forked; ventrals inserted slightly before origin of dorsal. Total length, 28.6; standard length, 22.9; length to vent, 14.4; length of head, 6.4; greatest depth, 4.5; diameter of eye, 2.2 millimeters. Myomeres, 19 to vent plus 17 behind. Body little compressed; head rather broad,

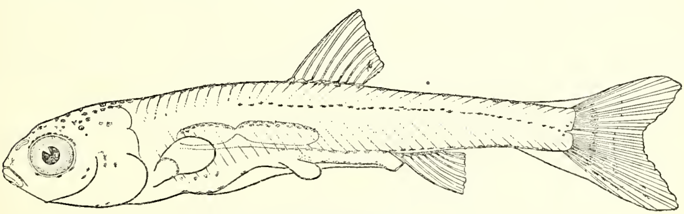

FIGURE 38.—*Notropis deliciosus stramineus,* 12 millimeters

snout very obtuse; mouth small, inferior, horizontal, lower jaw included. Characterized by dusky lateral band, not continued forward definitely through eye.

Pigmentation.—Heavy pigmentation occurs on upper jaw and over head, and is continued along dorsal aspect by 1 to 4 rows of round black chromatophores with small ones between. There is heavy marking around base of dorsal and behind dorsal. The chromatophores form a scalelike pattern to caudal. A few are evident on sides of head. The lateral line is marked irregularly by small light chromatophores to region of vent, then they become larger, blacker, and stellate. The ventral aspect is unmarked except for a double series of chromatophores posterior to vent. Pectorals, dorsal, and caudal are pigmented, but ventrals and anal are plain.

BREEDING

Spawning occurs during late June and early July in shallow inshore waters.

20. Notropis hudsonius (Clinton). Spot-tailed minnow. [*Hudsonius hudsonius* (DeWitt Clinton). Jordan, Evermann, Clark, p. 132.]

RECORD OF CAPTURE

Many ripe adults were taken in dip nets near Sturgeon Point in the middle of June, 1928, and one early larva tentatively assigned to this species, 5.2 millimeters long, was taken in a Helgoland trawl at 5 meters near Athol Spring on July 12. The straw-colored minnow is extremely abundant in the lake, and ascends some of the larger creeks.

DESCRIPTION

The present larva is characterized by a stout body and very blunt, bulbous head with large eyes and wide interorbital space, distinguishing it from *N. atherinoides* and

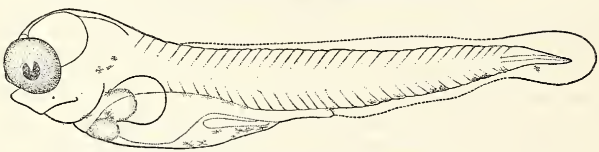

FIGURE 39.—*Notropis hudsonius*, 5 millimeters

N. deliciosus stramineus. Its small size compares unfavorably with specimens of *N. cornutus* of like development.

5.0-millimeter stage.—Total length, 5.0; length to vent, 2.75; greatest depth 0.96; diameter of eye, 0.5 millimeter. Myomeres, 17 to vent plus 15+ behind. Characterized by very blunt, bulbous head, with large eyes at the anterior margin and wide interorbital space; mouth moderate, inferior, lower jaw included. Large yellow oil globule anteriorly placed in stomach region.

Pigmentation.—A few chromatophores appear on sides of head, and many black stellate ones are distributed over ventral aspect to vent. About 4 very large subsurface chromatophores occur over top of stomach region, and 4 long, dark, linear patches behind vent on ventral ridge.

This species has general characters in common with *N. cornutus*, but its very small size compares unfavorably with specimens of like development of the latter. The head is too blunt and body too stout for young *N. deliciosus* or *N. atherinoides*. Quite possibly it is *N. hudsonius*, for many adults with ripe eggs were taken in a dip net near by at this time.

For comparison the description is given of a postlarval *N. hudsonius* taken at the mouth of Eighteen Mile Creek on July 18, 1928.

19.0-millimeter stage.—Dorsal, 8; anal, 9; caudal deeply forked; ventrals just anterior to dorsal origin, rays extending beyond vent. Total length, 19.0; standard length, 16.0; length to vent, 10.5; length of head, 4.2; greatest depth, 3.25 millimeters. Myomeres, 22 to vent plus 18 behind. Conical head with very blunt snout; small, nearly horizontal mouth, lower jaw shorter.

Pigmentation.—The 19-millimeter *N. hudsonius* is characterized especially by a definite black spot at base of caudal. The head is sparsely pigmented, and 3 rows of chromatophores are apparent on dorsal aspect to caudal. Small chromatophores are widely and irregularly placed in dorso-lateral region, and a few surface and subsurface chromatophores over operculum. A few occur below lateral line and subsurface chromatophores throughout its length, ending with a black spot at caudal. A double row extends backward from vent on ventral ridge. Dorsal and caudal are pigmented.

14.25-millimeter stage.—Total length, 14.25; standard length, 11.5; length to vent, 8.0; length of head, 3.0; snout, 0.6; diameter of eye, 1.0; greatest depth before vent, 2.1; depth behind vent, 1.5; length to dorsal, 6.0; to anal, 8.1 millimeters. Myomeres, 21 (22) to vent plus 16 behind. Dorsal I (rudimentary), 8; anal I (rudimentary), 9; ventrals immediately under front of dorsal; caudal rather long and forked. Body moderately elongate; head conical with short, blunt snout; mouth rather small, nearly horizontal; lower jaw very slightly shorter.

Pigmentation.—The head is more sparsely pigmented than in most other species of the genus. Chromatophores occur in about 3 rows along dorsal aspect, a few on operculum, and very many below surface on 2-chambered air bladder. A series

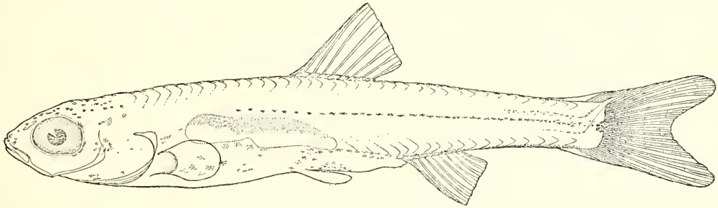

FIGURE 40.—*Notropis hudsonius*, 14.25 millimeters

marks the lateral line, surface and subsurface, and a prominent black spot is apparent at base of caudal. A few chromatophores occur beneath lower jaw, and a double series on ventral line backward from vent. The dorsal and caudal are pigmented.

BREEDING

The spot-tailed minnow spawns alongshore in late June and early July.

21. Notropis atherinoides Rafinesque. Lake shiner; emerald minnow.

RECORD OF CAPTURE

Only 6 small larvæ were taken in 1928, from July 30 to August 1, in the vicinity of Long Point Bay. During 1929, however, it was one of the most abundant species taken by the survey, as nearly every net towed from July 2 to August 20 contained from 1 to 500 of these larvæ. In the western part of the lake they were even more common between June 19 and August 17, as many as 3,000 being captured in a single tow. Adults are very common in the lake in deep as well as in shallow water.

DESCRIPTION

The newly hatched larva is characterized by its very slender unpigmented body with even the eyes colorless, clear elongate yolk, and myomere count of 23 to vent

plus 12 or 13 behind. It is most easily confused with *N. deliciosus stramineus* (see comparison on p. 332), but the myomere count and position of the ventrals which are inserted about 4 myomeres before the dorsal origin in this species are sufficient differences to distinguish the two.

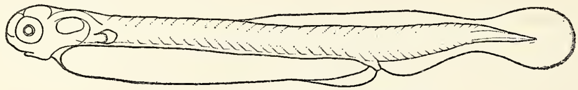

FIGURE 41.—*Notropis atherinoides*, 4.9 millimeters

4.9-millimeter stage.—Total length, 4.9; length to vent, 3.3; length of head, 0.7; snout, 0.08; diameter of eye, 0.22; greatest depth before vent, 0.63; depth behind vent, 0.57 millimeter. Myomeres, 23 to vent plus 13 behind. Dorsal marginal fin fold originating about 12–13 myomeres behind head, narrow, pinching at peduncle and widening around lophocercal tail; ventral marginal corresponding to dorsal contour; pectorals very small. Characterized by the exceedingly elongate colorless body,

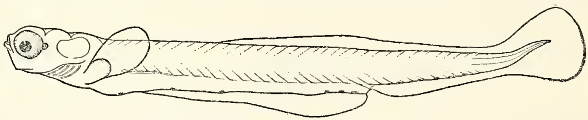

FIGURE 42.—*Notropis atherinoides*, 6.1 millimeters

colorless eyes, very elongate intestine, clear, elongate yolk which is granular in texture, and far inferior mouth.

6.1-millimeter stage.—Total length, 6.1; standard length, 5.9; length to vent, 4.0; length of head, 0.9; snout, 0.15; diameter of eye, 0.32; greatest depth before vent, 0.82; depth behind vent, 0.57 millimeter. Myomeres, 23 to vent plus 12 behind. Mouth small, terminal; marginal fins unchanged from preceding, but notochord turned slightly upward.

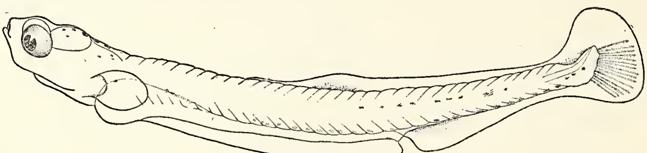

FIGURE 43.—*Notropis atherinoides*, 8.9 millimeters

Pigmentation.—The eye is pigmented with black, and about 9–10 very inconspicuous chromatophores extend along underside of intestine at wide intervals and along ventral ridge behind vent. Pigment on dorsal aspect of intestine is confined to one rather large linear patch at vent.

8.9-millimeter stage.—Total length, 8.9; standard length, 8.3; length to vent, 5.5; greatest depth, 1.0; diameter of eye, 0.4 millimeter. Myomeres, 22 to vent plus about 14 behind. Snout somewhat longer and more pointed than in 6.1-millimeter specimen but still shorter than eye; short head assuming the conic aspect of *N. atherinoides;*

long, slender, sharply compressed body, without elevation of back; very oblique mouth with upper lip on level of upper part of pupil; rather large eye; decurved lateral line; and position of dorsal fin, indicated by a concentration in the marginal fin fold beginning over the seventeenth myomere, identical with the position of the dorsal in adults of that species.

Pigmentation.—At this stage there are about 12 large black chromatophores on top of head, with no other dorsal coloration. Chromatophores occurring over

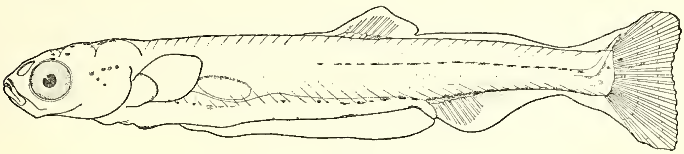

FIGURE 44.—*Notropis atherinoides*, 10.5 millimeters

air bladder and dorsal aspect of intestine are farther imbedded through the growth of the larva and thus are less evident. The chromatophores seen in previous stages along the ventral aspect of intestine have disappeared, with the exception of a very large one just before vent; this one ventral spot is conspicuous in the next stage described and figured. At the posterior end of body the ventral line chromatophores follow the notochord upward. Starting just before the vent, a single series of about 9 linear chromatophores marks the lateral line.

10.5-millimeter stage.—Total length, 10.5; standard length, 9.5; length to vent, 6.7; length of head, 2.0; snout, 0.43; diameter of eye, 0.7; greatest depth before vent, 1.64; depth behind vent, 0.95 millimeter. Myomeres, 22 to vent plus 16 behind.

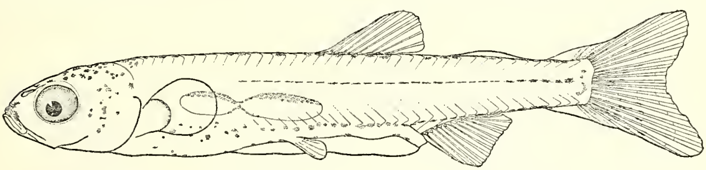

FIGURE 45.—*Notropis atherinoides*, 13.5 millimeters

Marginal fin fold has disappeared dorsally before the origin of permanent dorsal at about the sixteenth myomere. Dorsal definitely shaped with elements and eight partially-formed rays evident. Embryonic fin persisting behind dorsal as a narrow marginal band continuous with the heterocercal caudal; caudal rays formed but distal margin only slightly emarginate. Embryonic marginal persisting ventrally.

Pigmentation.—Chromatophores occur as in preceding stages with additional surface spots on snout and caudal, and subsurface spots in gill and isthmus regions, over 1-chambered air bladder, along dorsal aspect of notochord, and at end of body forming a caudal spot.

13.5-millimeter stage.—Total length, 13.5; standard length, 11.5; length to vent, 8.0; length of head, 3.0; snout, 0.7; diameter of eye, 0.81; greatest depth before vent, 2.0; depth behind vent, 1.5 millimeters. Myomeres, 22 to vent plus 16 behind. Dorsal, 8; anal, 11, completely formed; only tiny portion of embryonic fin fold behind

dorsal, but persisting entirely on underside before the vent; ventrals apparent, placed well forward, about 4 myomeres before origin of dorsal; caudal large and deeply forked. The young fish has most of the characters of the adult at this stage. Body elongate; snout short and somewhat pointed; eye large; mouth oblique, reaching to front of eye.

Pigmentation.—Chromatophores appear on both jaws, over top of head, and in an irregular double dorsal series to caudal, most prominent at base of dorsal and near caudal. A few occur on cheeks and on lateral line in a single series, linear-shaped, becoming larger toward caudal. On sides of stomach before ventrals, there are about 10 at wide intervals on ventral margin before vent, and a conspicuous double series on ventral line from vent to caudal. Subsurface chromatophores are evident on brain, gills, isthmus, over 2-chambered air bladder, covering dorsal surface of notochord, and a group at extreme end of body forming a subsurface caudal spot. The fins are colorless except for the caudal.

BREEDING

Our records show that hatching occurred from the middle of June until after the middle of August.

22. Notropis rubrifrons (Cope). Rosy-faced minnow.

RECORD OF CAPTURE

This minnow is not common in the Lake Erie region. Specimens have been recorded from Lake Erie but the species is limited mostly to several of the larger streams where there is a strong current.

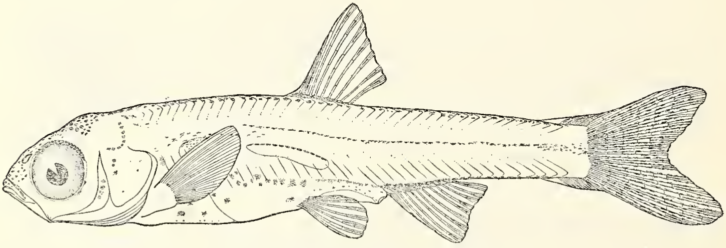

FIGURE 46.—*Notropis rubrifrons*, 15 millimeters

DESCRIPTION

The rosy-faced minnow is distinguished by its comparatively thick heavy body and pronounced sharp snout.

15.0-millimeter stage.—Total length, 15.0; standard length, 12.0; length to vent, 8.0; length of head, 3.2; snout, 0.75; diameter of eye, 1.1; greatest depth before vent, 2.6; depth behind vent, 1.6; length to dorsal, 6.8; to anal, 8.25 millimeters. Myomeres, 22 to vent plus 17 behind. Dorsal II (rudimentary), 8, origin at about middle of body; anal II (rudimentary), 10; caudal moderate. Body moderately stout; head rather large, snout long and pointed; eye large; mouth oblique, maxilla reaching to front of eye.

Pigmentation.—Chromatophores extend across upper jaw, heavily over top of head, and in 3 or 4 uncrowded rows on dorsal line from head to caudal. A few occur in gill region on surface and below surface, and in a single series along lateral line, more numerous near caudal. There are many below the surface in the abdominal region, and one row on either side of ventral aspect backward from vent. The caudal is the only pigmented fin.

BREEDING

This species is a spring breeder, at which time the male develops tubercles on the snout, and crimson color on forehead, opercular region, and base of dorsal.

23. Notropis cornutus chrysocephalus Rafinesque. Common shiner; red-fin shiner. [*Luxilus cornutus chrysocephalus* (Rafinesque). Jordan, Evermann, Clark, p. 128.]

RECORD OF CAPTURE

In 1928 no specimens were taken from Lake Erie, but spawning adults and a large number of eggs and larvæ were found in a tributary creek on June 14. The development of these eggs is recorded in the following stages to 10.5 millimeters. One larva was taken in the lake on June 19, 1929, off Point Pelee at the surface in water 12½ meters deep, and a number in a somewhat later stage of development at the tip of Long Point on July 8. Adults are abundant in the region.

DESCRIPTION

This shiner is most easily recognized at all stages from *N. atherinoides* by its deeper body, but with more difficulty from *N. deliciosus stramineus*. At 7 millimeters pigmentation in the two is alike except that *N. cornutus chrysocephalus* has no dorsal chromatophores behind the head while the other species have a double series to origin of dorsal. In postlarval stages the difference in dorsal and anal fin-ray counts is diagnostic.

Egg.—Mass rather loosely attached, but a few eggs tightly held together with bits of gravel adhering. Diameter of living egg, 1.45 to 1.9 millimeters, mostly about 1.6 millimeters. Diameter of clear, yellow oil globule 0.5 to 0.6 millimeter. Eggs in early cleavage seem to have very little oil diffused through yolk, and embryo stages have one large globule and often many tiny ones closely associated with it and over yolk.

Figure 47*A* shows the earliest stage observed, with blastodisc well formed. There seems to be a small amount of oil diffused through yolk.

Figure 47*B* with the embryo completely circling yolk, shows brain well formed, eyes lightly pigmented in black, and small, black stellate chromatophores over yolk. Both of the above stages were observed on June 18.

One week after the stage shown in Figure 47*B* two specimens were hatched and thriving, swimming rapidly around the aquarium and almost constantly on their sides. The larva (fig. 48) was very transparent, only the yellowish yolk and dark eyes being evident to the naked eye of the observer. The measurements were: Total length, 6.9; length to vent, 3.6; greatest depth, 1.75; diameter of eye, 0.4 millimeter. Large oil globule persisting in anterior region of yolk; black chromatophores over yolk sac and an uneven series along ventral ridge of tail, extending up a little over sides. Two days after hatching the total length of the larva had not increased,

but the body was much deeper behind vent. Total length of preserved specimens, 6.5; length to vent, 3.7; greatest depth, 1.9; diameter of eye, 0.5 millimeter. Myomeres, 14 to vent plus 19 behind (not completely developed). Yolk much smaller, having changed its rounded egglike shape for an almost square contour with only

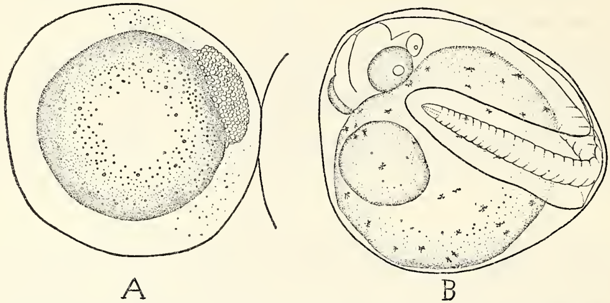

FIGURE 47—*Notropis cornutus chrysocephalus.* A, egg with blastodisc formed. B, egg with late embryo

the corners rounded; oil globule anterior to yolk, not contained within it as in the previous stage.

Pigmentation.—Yellow chromatophores occur over oil globule and head as before, but many large gray stellate ones are added over top and sides of head. Chromatophores persist on underside of yolk and those on sides of embryo are arranged in an irregular double line from the antero-ventral region of yolk sac to its postero-dorsal limit, becoming continuous with the ventral ridge series. Toward the end of tail 5 or 6 chromatophores follow up the grooves of the myomeres as black

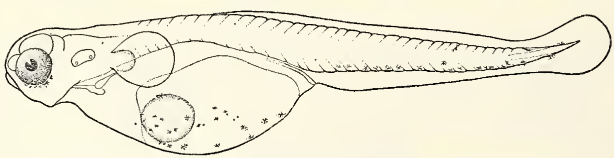

FIGURE 48.—*Notropis cornutus chrysocephalus*, larva immediately after hatching, 6.9 millimeters

streaks, almost to lateral line. A subsurface series starts at base of brain and continues along dorsal surface of nerve chord almost to tail, made up of about 17 to 20 very large roundish stellate chromatophores appearing gray through the myomeres. Another group (both surface and subsurface) extends along lateral line (about 10 to 14), and a third subsurface series starts over yolk sac and continues to caudal about halfway between the ventral ridge and the lower margin of notochord.

7.0-millimeter stage.—Total length, 7.0; length to vent, 4.6; length of head, 1.3; greatest depth, 1.0; diameter of eye, 0.5 millimeter. Myomeres, 21 (22) to vent plus about 14 behind (incomplete). Head blunt, eye very large, jaws equal; mouth terminal, median; air bladder large, one chambered at this 3-day-old stage.

Pigmentation.—The air bladder is covered dorsally by very large, black, roundish chromatophores. About 12 large, round, black chromatophores occur on top of

head, large stellate subsurface ones on underside of brain, and 2 on dorsal ridge near caudal. There are subsurface chromatophores at base of pectorals and a double arrow-shaped series on underside in gill region. The underside of stomach region has 2 to 4 uneven rows of rather small, round chromatophores, becoming irregular and single from intestine to vent (about 17 in this single series). The large air-bladder patch is continued as a double line of subsurface chromatophores to vent, thence as a double line of smaller surface ones to end of body (about 16). A few

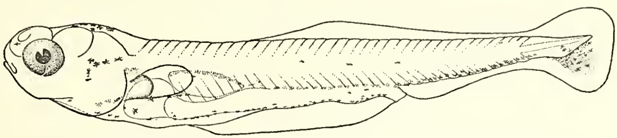

FIGURE 49.—*Notropis cornutus chrysocephalus*, 7 millimeters. (Drawn from living specimen)

appear on caudal. The oblique line over yolk sac of younger stages is represented by a very few (about 6) chromatophores in the same position across the stomach. The marking is considerably variable in individuals, especially that on lateral line. In some 7-millimeter specimens the line is completely marked by linear chromatophores, while in others of larger size only a few such spots appear, and in a few none. The dorsal marking varies likewise. In some specimens this aspect is colorless, while in others a double line of rather large chromatophores occurs toward the anterior end.

7.5-millimeter stage.—A very slight concentration at future location of dorsal and anal fins discernible; caudal still lophocercal, but with a few rays developed ventrally.

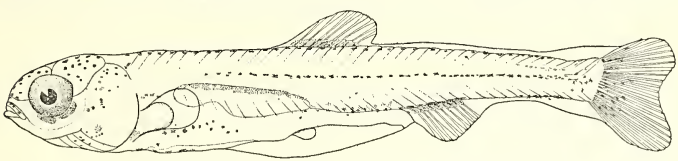

FIGURE 50.—*Notropis cornutus chrysocephalus*, 11 millimeters

8.5-millimeter stage.—Concentration greater in embryonic marginal fin-fold but no rays; fin fold, however, more pinched; notochord turned abruptly upward at caudal.

10.5 millimeter stage.—All elements of dorsal and anal complete, and about half of dorsal rays developed; no sign of ventrals.

11.0-millimeter stage.—Dorsal, 8; anal, 9; elements and fin-rays complete. Total length, 11.0; standard length, 9.9; length to vent, 7.0; greatest depth, 1.7; diameter of eye, 0.9 millimeter. Myomeres, 21 to vent plus about 17 behind. Air bladder constricted considerably. Ventrals apparent, but very small and unrayed, with embryonic marginal fin fold persistent beneath them from below constriction of air bladder to vent.

Pigmentation.—The marking here is essentially as in previous stages. The snout, interorbital region, and top of head are covered with very large, roundish chromatophores. Subsurface series occur below brain and gill regions and very

small surface chromatophores on sides and beneath head. The lateral line is well marked by about 45 chromatophores, starting over anterior portion of air bladder. Subsurface chromatophores appear over forward part of stomach region, becoming very numerous and heavy over both lobes of air bladder, and are continued behind over dorsal aspect of intestine to vent. About 12 surface chromatophores, also, occur along intestine. The lateral stomach series is continuous with the subsurface gill series. Ventral chromatophores start between pectorals and run in a most irregular, usually single but sometimes double line to vent. Anteriorly, these ventral spots are rather large, but as the line approaches the vent, they become very small and numerous. From the vent backward a double series of large stellate chromatophores extends on ventral ridge to end of body (about 22). The pigmented caudal has many small chromatophores concentrated at its base but not in great enough numbers to indicate a caudal spot. Two subsurface longitudinal series parallel with the lateral line are faintly distinguishable through the myomeres, one halfway between dorsal and median lines, and the other between median and ventral lines. These last series were first seen in the 2-day stage.

13.2-millimeter stage.—Total length, 13.2; standard length, 11.5; length to vent, 8.1; head, 3.0; snout, 0.55; diameter of eye, 1.1; greatest depth before vent, 2.3;

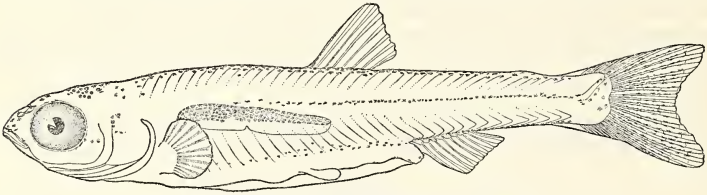

FIGURE 51.—*Notropis cornutus chrysocephalus*, 13.2 millimeters

depth behind vent, 1.4; length to dorsal, 6.0; to anal, 8.2 millimeters. Myomeres, 21 to vent plus 15+ behind. Dorsal, 8; anal, 9. Differs from preceding stage in the completion of the vertical fins, further development of ventrals, and more adult aspect of the head.

Other specimens of 18.5 and 21.3 millimeters in collection show no essential changes in pigmentation.

BREEDING

The common shiner spawns during June and the first half of July on shallow gravel bottom. Breeding activity is interestingly recorded by Dr. G. C. Embody and W. J. Hamilton, jr. (Greeley, 1927). Many adults of *Notropis cornutus frontalis*, seined on July 9, 1928, at Grand Island, contained ripe ova. Spawning of the latter upstream subspecies was observed by members of the survey group on June 17, 1928, in Little Buffalo Creek and on July 9 in Silver Creek (Greeley, 1928).

24. Notemigonus crysoleucas crysoleucas (Mitchill). Golden shiner. [*Notemigonus crysoleucas* (Mitchill). Jordan, Evermann, Clark, p. 115.]

RECORD OF CAPTURE

This species is commonly taken in weedy, sheltered bays of Lake Erie and in many weedy streams and ponds.

DESCRIPTION

A very significant field character in the specimens at hand is the golden tinge which covers more or less of the whole body, always deep through head region, on all fins, and caudal peduncle. The profile of the head is quite concave above in the younger stages, and the upper lip is on a level with the upper margin of pupil.

18.0-millimeter stage.—Total length, 18.0; standard length, 14.5; length to vent, 9.6; length of head, 4.0; snout, 0.6; diameter of eye, 1.5; greatest depth before vent, 3.2; depth behind vent, 2.1; length to dorsal, 8.0 millimeters. Myomeres, 20 (21) before vent plus 17 behind. Dorsal I (rudimentary), 8; anal I (rudimentary), 11–12; all fins rather long. Characterized by comparatively short head (although proportionately larger than in later stages) with pointed snout; small, terminal, oblique mouth barely reaching front of large eye. Body slender, elongate, somewhat compressed, especially slender in tail region. Dorsal higher than long, situated in middle

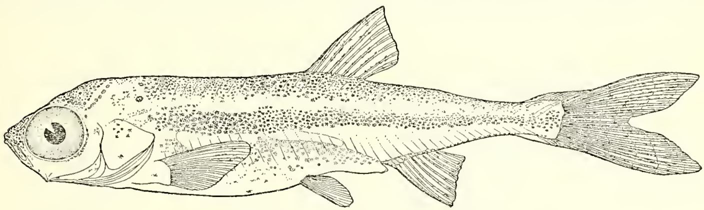

FIGURE 52.—*Notemigonus crysoleucas*, 18 millimeters

of body opposite space between ventrals and anal; anal longer than dorsal; caudal long and deeply forked.

Vertebræ in stained specimen, 21 plus 19. The character of the head, as described above, is diagnostic.

Pigmentation.—Brownish-black chromatophores appear thickly on both jaws, top of head, dorsal aspect extending down over the sides and in a broad lateral band from head to caudal. Below the surface they occur abundantly in the abdominal region. There is a double series on ventral aspect from vent backward, and all fins are pigmented. A brilliant golden tinge completely covers some specimens, and all are colored thus about the head, the fins, and caudal peduncle.

The 24-millimeter specimen, which is fully scaled, shows a fleshy keel on the belly behind the ventral fins, over which the scales do not pass. In this stage, too, the head is becoming conic.

BREEDING

The golden shiner spawns from May until early summer.

25. Hyborhynchus notatus (Rafinesque). Blunt-nosed minnow.

RECORD OF CAPTURE

The blunt-nosed minnow is common in sheltered bays of Lake Erie and in the larger streams and ponds near-by. The eggs and young described here were taken in Sister Creek on July 13, 1928, from a nest guarded by a male *H. notatus* (described under Breeding, p. 347).

DESCRIPTION

Egg.—Outer diameter of egg, 1.5 millimeters; diameter of yolk, 1.3 millimeters in specimens having large blastodisc formed; yolk very granular, yellowish.

Figure 53 shows egg with outer diameter, 1.5 millimeters; inner diameter, 1.05 millimeters; embryo about two-thirds around egg; anterior portion of yolk very large and round, followed by an elongated portion beyond which the tail is free; myomeres evident from the end of bulbous portion of yolk to tip of tail; optic vesicles, brain divisions, and notochord apparent. No chromatophores; yolk yellow.

The stage shown in Figure 55 has the embryo coiled more than once around egg, tail reaching to back of head; pectorals very well developed; myomeres completely formed; pigment confined to eyes.

Newly hatched larva.—Total length, 4.6; length to vent, 3.0; greatest depth, 1.25; diameter of eye, 0.45 millimeters. Myomeres, about 20 to vent plus about 12 behind (very incomplete). Characterized by very large club-shaped yolk sac, consisting of

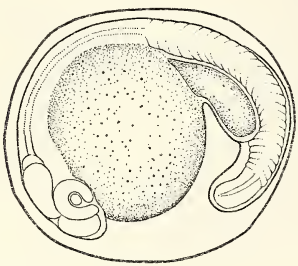

FIGURE 53

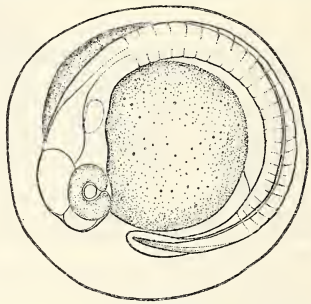

FIGURE 54

Hyborhynchus notatus eggs showing typical formation in the embryo. (Drawn from living eggs)

large bulbous portion without definite oil globules but with some oily substance throughout, and narrow, extended posterior portion reaching to vent. Mouth and vent not open. Tail lophocercal; embryonic marginal fin originating at about the tenth myomere, low and even, continued around caudal to vent; pectorals developed but small.

Pigmentation.—The larva is colorless, except for deep gray eyes with a golden tinge, some deep orange over yolk, and two very large stellate chromatophores on underside of yolk sac at vent, barely discernible.

Larva 1 day old.—Total length, 5.0; length to vent, 3.0; greatest depth, 1.0; diameter of eye, 0.4 millimeters. Myomeres, 19 before vent plus 14 behind (incomplete). Bulbous part of yolk sac reduced and posterior part heavier. Marginal fin fold intact, slightly raised before vent, and somewhat notched at caudal peduncle.

Pigmentation.—A very few large delicate chromatophores occur beneath and on sides of yolk sac (some specimens without), an uneven series on ventral aspect from vent backward and two chromatophores on lateral line just before vent.

3 days old.—Total length, 5.5 to 5.7 millimeters. Body much heavier; interorbital space wide; yolk sac greatly reduced, retaining elongated shape, now tapering

slightly and evenly to vent without constriction; marginal fin fold intact; pectorals larger but not rayed.

Pigmentation.—The yolk is yellowish in color. Ventral chromatophores are now arranged in a double row of large stellate spots from before middle of yolk to vent, and are continued in a double row behind, much closer together. Many chromatophores occur over air bladder, and a row of 4 over last one-third of yolk sac. Over these last, and corresponding in position, there is a row of 5 chromatophores on lateral line. Two chromatophores are apparent before each pectoral and 2 behind.

4 days old.—Total length, 6.0 millimeters. Body very deep with yolk sac almost if not entirely absorbed. Marginal fin fold intact, continued forward on the ventral side corresponding to the dorsal; pectorals very large.

Pigmentation.—The eyes are metallic blue and black, and the cardiac region and blood stream are greenish yellow. Chromatophores grouped as before.

1 week old.—Total length, 6.0; length to vent, 3.75; greatest depth, 0.9 millimeter. Myomeres, about 21 to vent plus about 13 behind. Total length of larva not changed since the age of 4 days, but body assuming more advanced development and proportions; yolk absorbed; vent somewhat farther back and more myomeres developed forward.

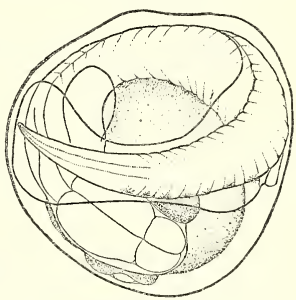

FIGURE 55.—*Hyborhynchus notatus* egg with late embryo. (Drawn from living egg)

Pigmentation.—The pigmentation is generally unchanged in this stage, but intensified, consisting of chromatophores sparsely distributed on top of head and anterior dorsal aspect, a few on sides of head, a series of large chromatophores rather far apart along lateral line from behind air bladder to end of body, and 1 large subsurface spot at base of pectoral. The top of air bladder is very darkly pigmented, and 3 large round chromatophores follow the curve of gill arch below on each side of throat region. Behind and parallel with these, and before the air bladder occur a double series of about 6 to 8 large stellate spots. On the under side, from middle of stomach region to vent, about 4 lines of similar chromatophores appear, followed by a conspicuous double series on ventral ridge to end of body. A few are evident on ventral part of caudal.

2-weeks old.—Total length, 6.5; length to vent, 4.0; greatest depth 0.82; diameter of eye, 0.4 millimeter. Myomeres, about 21 before vent plus about 15 behind (incomplete). General shape and pigmentation unchanged, except that more color is evident.

Pigmentation.—A yellowish tinge extends over top of head and along dorsal ridge to end of body. The top of stomach region is faint yellowish with numerous, small, raised yellow spots as though superimposed upon the heavy black chromatophores of the air bladder. The eye is very iridescent with lavender, pink, blue, and yellow casts on a brilliant silver background. Over the air bladder a short region of iridescence similar to that of the eye is evident on a line with the median black chromatophores running along top of intestine. This is apparently the beginning of the silvery adult condition.

The influence of artificial rearing upon the normal growth of the larva was evident with these specimens. One little fish was kept living for 10 weeks during which time it fed actively on prepared crushed insect food. The fins and other adult characters

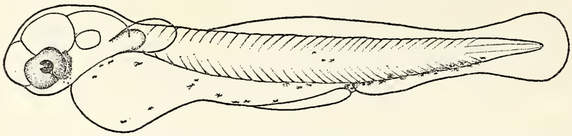

FIGURE 56.—*Hyborhynchus notatus* larva, 1 day old, 5 millimeters. (Drawn from living specimen)

developed normally, but the young fish grew only to a length of 10 millimeters. Under natural conditions it would undoubtedly have been very much larger.

12.0-millimeter stage.—Total length, 12.0; standard length, 10.25; length to vent, 7.0; length of head, 2.6; snout, 0.45; diameter of eye, 1.0; greatest depth before vent, 1.6; depth behind vent, 1.0; length to dorsal, 5.5; to anal, 7.1 millimeters. Myomeres,

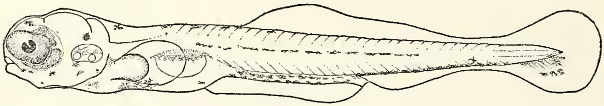

FIGURE 57.—*Hyborhynchus notatus*, 1 week old, 6 millimeters. (Drawn from living specimen)

21 to vent plus 15 behind. Characterized by abruptly decurved snout, inferior horizontal mouth with lower jaw included; slender body and somewhat depressed back; slender caudal peduncle; light peritoneum (although in 17.75-millimeter specimen quite dark). Dorsal I (rudimentary), 8; anal I (rudimentary), 7.

Pigmentation.—The 12-millimeter specimen is characterized by a black spot at base of caudal as in many cyprinids, and the fact that although diffuse chroma-

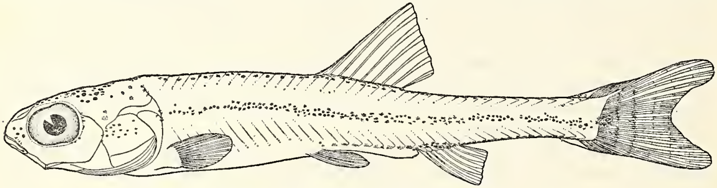

FIGURE 58.—*Hyborhynchus notatus*, 12 millimeters

tophores over snout and cheek suggest a band, the real lateral band starts most decidedly behind the head and is less conspicuous than in the other lateral-banded cyprinids. Chromatophores occur also on top of the head and along the whole dorsal aspect in irregular longitudinal rows, more concentrated at base of dorsal and below the surface dorsally on the intestine. Many are grouped on surface around base of anal and thence in a double row to base of caudal. A few appear on pectorals and caudal. Sides of body, except for lateral band, and belly are colorless.

Young adult stage.—Dorsal, 9 (first ray enlarged); anal, 7; caudal forked; ventrals midway between pectorals and anal. Total length, 17.75; standard length, 14.5;

length of head, 3.75; length to vent, 10.25; greatest depth, 2.8; diameter of eye, 1.5 millimeters. Myomeres, about 23 to vent plus 16 behind. Mouth inferior, horizontal, lower jaw included; snout abruptly decurved; body slender with depressed back and slender caudal peduncle.

Pigmentation.—The young adult is characterized by a very prominent round black spot at base of caudal, and a lateral pigment band, which starts behind the head and is narrower and less noticeable than in *Semotilus*, *Campostoma*, and other banded minnows. The top of head has many round chromatophores and smaller, longitudinal rows extend along dorsal aspect of body, irregularly marked, with a concentration of larger ones at base of dorsal fin. Above the lateral band only a very few scattered pigment cells are present, and none below, with the exception of a series 2 to 4 chromatophores in width at anal base, and a double line on ventral edge behind vent to caudal. Dorsal, caudal, and pectorals are marked. The peritoneum is blackish.

BREEDING

The breeding season of the blunt-nosed minnow extends from late spring until late summer. During this time the male develops 14 to 17 large tubercles on snout, the head and front part of dorsal fin become black, and often the lower fins take on an orange hue. John Greeley (1929) observed the eggs near the mouth of Sister Creek on July 13.

> They adhered, individually, to the underside of a large, flat stone, and covered an area 7 by 4½ inches. The total number, accurately estimated, was 11,812. These were laid by more than one female, judging by the fact that some were hatching when found, and others were far less advanced. The eggs were guarded, when found, by a male fish approximately 3¼ inches long, whose position was directly under the stone. The water temperature was 82 degrees. It is interesting, in its bearing on the subject of the efficiency of natural fertilization of fish eggs, to note that everyone of these was fertile with live embryo.

26. **Pimephales promelas promelas** Rafinesque. Fat-head minnow; black-head minnow. [*Pimephales promelas* Rafinesque. Jordan, Evermann, Clark, p. 145.]

RECORD OF CAPTURE

The fat-head minnow was found commonly at the mouths of several tributaries to Lake Erie, and in greater numbers in several small ponds nearby.

DESCRIPTION

The present species differs from the closely related *H. notatus* in its much stouter, shorter body and lack of a very distinct round black spot at base of caudal. Although there are some chromatophores in *Pimephales* in this region, they are mostly subsurface and the lateral band is considerably lighter.

11.6-millimeter stage.—Total length, 11.6; standard length, 10.2; length to vent, 6.8; length of head, 2.65; diameter of eye, 0.8; greatest depth to vent, 2.19; depth behind vent, 1.35; length to dorsal, 5.25; to anal, 7.0 millimeters. Myomeres, 20 to vent plus 16 behind. Dorsal I (rudimentary), 8; anal I (rudimentary), 7; ventrals small, unrayed, inserted immediately below dorsal origin; caudal moderately forked. Body rather robust; head short with obtuse snout; mouth very small, terminal, oblique.

Pigmentation.—Chromatophore marking is not heavy but limited principally to snout, top of head, a wide dorsal series (3–6 lines wide) to caudal, and a single series along lateral line to caudal, in which the spots are rather close together, being round anteriorly and more linear posteriorly. Many occur also below the surface over stomach-intestinal region, followed by a double surface series on dorsal ridge from vent to caudal, spreading rather widely around anal base. There is a subsurface concentration at base of caudal. A few chromatophores are evident on dorsal and many on caudal.

BREEDING

The fat-head minnow spawns throughout the summer, at which time the head of the male becomes jet-black, the caudal peduncle dusky, and the snout covered with

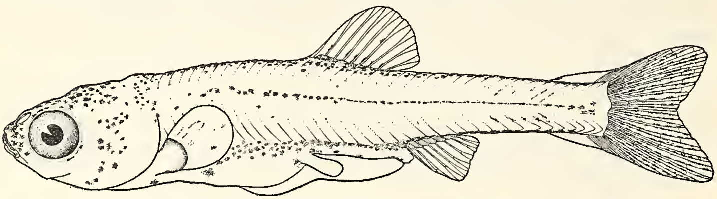

FIGURE 59.—*Pimephales promelas promelas*, 11.6 millimeters

about 14 coarse tubercles. Greeley (1927) reported spawning on June 22. The round opaque eggs, one-sixteenth inch in diameter, were attached side by side in a mass to the underside of a stick immersed in 8 inches of water at a temperature of 67° F. There were approximately 700 eggs in the mass.

27. Campostoma anomalum (Rafinesque). Stone-roller minnow.

RECORD OF CAPTURE

Although straying rarely into Lake Erie, the stone-roller minnow frequents warm, shallow streams.

DESCRIPTION

The remarkably elongate intestine which winds in spiral fashion around the air bladder is peculiar to *Campostoma*. The differences between this species and *Semotilus atromaculatus atromaculatus*, with which it is readily confused, are discussed on page 329.

9.75-millimeter stage.—Total length, 9.75; standard length, 9.2; length to vent, 6.35; length of head, 1.9; diameter of eye, 0.7; greatest depth to vent, 1.3; depth behind vent, 0.6 millimeter. Myomeres, about 24 to vent plus 14+behind. Marginal fin fold frayed but probably arising over air bladder and extending to caudal, low; somewhat broader ventrally; caudal heterocercal with rays forming. Body moderately elongate at this stage; snout obtuse; mouth small, terminal; peritoneum black.

Pigmentation.—Black chromatophores are heavy on lips, snout, top and sides of head, and in a double series of about 50 on dorsal ridge. These ridge chromatophores are exceptionally large and have about 3 other rows between the double

series. A single series occurs on lateral line from behind head to caudal, representing the broad lateral band of the adult. Others are apparent over gill region, stomach region, and along dorsal aspect of intestine below the surface, a few below head, followed by a short double series of about 9 in the jugular region, and a prominent double series to caudal.

BREEDING

The stone-roller minnow spawns in the spring, running up small brooks for the purpose, depositing its eggs among the stones near shore. In the breeding season the males have the head or even the whole body covered with large, round tubercles,

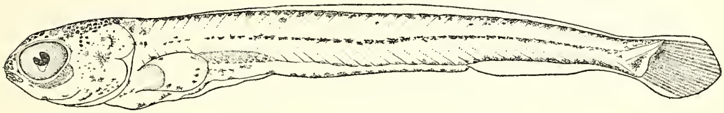

FIGURE 60.—*Campostoma anomalum*, 9.75 millimeters

which are more extensively developed than in other cyprinids. The iris becomes orange, and the dorsal and anal fins on either side of the dusky crossbar are fiery red.

Family AMEIURIDÆ Catfishes

23. Ictalurus punctatus (Rafinesque). Spotted catfish, silver cat; channel cat.

RECORD OF CAPTURE

This catfish is common in Lake Erie, the Niagara River, and the larger tributary streams of the Niagara. Its young frequent sheltered bays and the mouths of creeks.

DESCRIPTION

The more slender, elongate body, compressed posteriorly, and the forked tail, as well as the joining of supra-occipital and predorsal processes to form a bony ridge between head and dorsal fin, and the free posterior margin of adipose distinguishes it from *Noturus* and *Schilbeodes*.

32.6-millimeter stage.—Total length, 32.6; standard length, 26.9; length to vent, 13.0; length of head, 7.8; greatest depth before vent, 6.3; depth behind vent, 5.0; diameter of eye, 2.0 millimeters. Vertebrae, about 16 to vent plus 28 behind. Dorsal I, 6; anal 24 (26 apparent in stained specimen); posterior margin of adipose free; caudal forked. Body slender; head slightly convex above; very long maxillary barbels, longer than head; pectoral spine about two-thirds length of head; slender humeral process about one-half length of pectoral spine.

Pigmentation.—The body is nearly white with tiny brownish chromatophores sparsely distributed over entire surface. The heavier subsurface spots occurring over stomach region are emphasized by clearing. All fins are marked with very small chromatophores.

BREEDING

The spotted catfish spawns in June in weedy places near shore.

29. Ameiurus nebulosus (LeSueur). Common bullhead; horned pout.

RECORD OF CAPTURE

The common bullhead is restricted to the sheltered bays of Lake Erie, and the larger, sluggish streams and ponds of the region.

DESCRIPTION

The bullhead is easily distinguished from *Ictalurus* by its rounded or truncate tail, broad head, and a complete separation of supra-occipital and predorsal processes; from *Villarius* (which also has separate processes) by its rounded tail; from *Noturus* by the free posterior margin of adipose; and from *Ameiurus natalis* by the anal rays, 21 to 24 (*natalis* usually has 25 or 26), and by its gray to black mental barbels, usually white in *natalis*.

22-millimeter stage.—Total length, 22.0; standard length, 18.5; length to vent, 9.9; length of head, 5.7; greatest depth before vent, 4.5; depth behind vent, 3.5; diameter of eye, 1.05 millimeters. Vertebræ apparent, 14 to vent plus 26 behind. Dorsal I, 6; anal 21; caudal short, stout, and rounded or square. Eight barbels; maxillary barbels about as long as head.

Pigmentation.—The body is entirely covered with small, round, close-set chromatophores giving an even gray color. The chromatophores are heaviest over top and sides of head, on dorsal aspect of body, and fins and lightest in belly region. All barbels are dark.

BREEDING

C. W. Nash (1908) describes the spawning of the bullhead thus:

Early in June, when about to spawn, the catfishes select a spot in quiet shallow water near aquatic weeds and there they make a nest, from eight inches to one foot in diameter, by clearing out a slight depression in the mud or sand. In this nest about two thousand eggs are deposited, over which the parents keep guard, the male being most assiduous in the work of protection. In about a week the eggs are hatched and the young, which look very like little black tadpoles, follow the parent fish along the shores until nearly the middle of July, when they are left to shift for themselves; after this the fry soon scatter and disappear into deep, weedy water. They grow rapidly, and, under favorable circumstances, are said to attain maturity in three years.

30. Ameiurus natalis (LeSueur). Yellow catfish.

RECORD OF CAPTURE

This catfish is much rarer than the common bullhead, being found by the survey only at Dunkirk Bay in Lake Erie, and in Muddy and Little Sister Creeks.

DESCRIPTION

The yellow catfish is distinguished from the common bullhead by anal rays, 25 or 26 (*nebulosus* has 21 to 24), and white mental barbels (gray to black in *nebulosus*). An exception occurs when the specimen is found on a dark bottom, in which case these barbels may be dusky. Distinguishing characters of the genus are considered under *A. nebulosus*, above.

FIGURE 61.—*Ictalurus punctatus*, 32.6 millimeters. Specimen stained and cleared

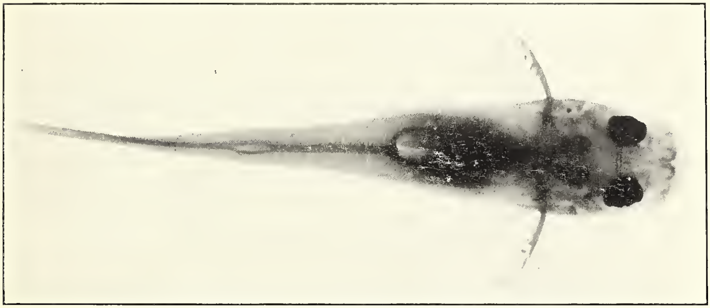

FIGURE 62.—*Ictalurus punctatus*, 22.6 millimeters. Dorsal view of cleared specimen

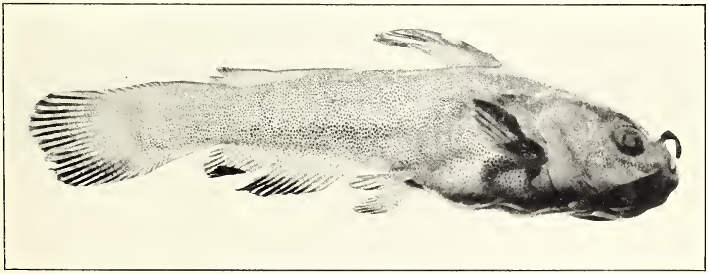

FIGURE 63.—*Ameiurus nebulosus*, 22 millimeters

FIGURE 64.—*Ameiurus nebulosus*, 24 millimeters. Specimen stained and cleared

FIGURE 65.—*Ameiurus natalis*, 17 millimeters

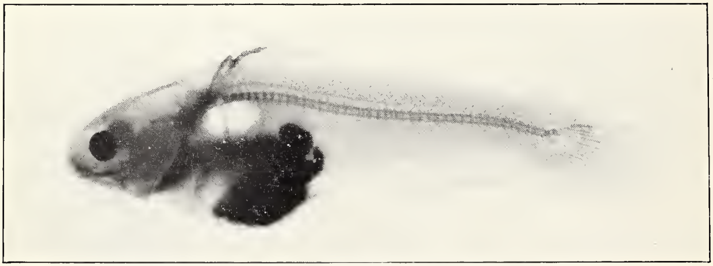

FIGURE 66.—*Ameiurus natalis*, 17 millimeters. Specimen stained and cleared

17-millimeter stage.—Total length, 17.0; standard length, 14.0; length to vent, 7.6; length of head, 4.5; greatest depth before vent, 5.0; depth behind vent, 2.8; diameter of eye, 0.9 millimeter. Vertebræ, about 15 to vent plus 27 behind. Dorsal I, 6; anal, 24; caudal, rounded. Body heavy; head broad; maxillary barbel as long as head; dorsal and pectoral spines very strong, shorter than soft rays.

Pigmentation.—The young *A. natalis* is covered with small, round, closely set chromatophores which give a gray color to head, body, and fins, as in *A. nebulosus*, but it differs from the latter in having the whole underside of head and stomach from behind lower jaw to vent perfectly colorless. The white barbels below the chin are an easy field character for identifying this species.

BREEDING

The yellow catfish spawns in June, and its breeding habits are probably similar to those of *A. nebulosus.*

31. Noturus flavus Rafinesque. Stonecat; mongrel bullhead; deep-water bullhead.

RECORD OF CAPTURE

The stonecat is common in Lake Erie along rocky shores, ranging out into water at least 30 feet deep, and in the larger tributary streams over stony bottom.

DESCRIPTION

The yellow stonecat is distinguished immediately from other catfishes, except *Schilbeodes*, by the fact that the adipose fin has its posterior margin adnate to back, separated from margin of caudal only by an incomplete notch, if at all. The premaxillary teeth have backward lateral extensions which differ from the more delicate, smoother ones of *Schilbeodes.*

20.0-millimeter stage.—Total length, 20.0; length to vent, 10.1; length of head, 4.9; snout, 2.1; eye, 1.2; greatest depth before vent, 4.05; depth behind vent, 2.8 millimeters. Dorsal I (short), 6; anal, 16; low adipose begins over origin of anal, continuous in this specimen to caudal; pectoral spine retrorsely serrate in front, slightly rough behind. Body elongate, head very depressed, flat, nearly as broad as long; barbels short.

Pigmentation.—The little stonecat is yellowish with small black chromatophores uniformly distributed over top and sides of body, thickest over head. The belly is white. Chromatophores extend from body on to adipose and caudal. Other fins are unmarked. The barbels are very lightly spotted with chromatophores.

BREEDING

John Greeley (1929) reports two egg masses of the stonecat found during the survey under flat stones in lower Sister Creek on July 13, 1928, at a temperature of 82° F. Two fishes, probably the parents, guarded one mass, while the male was hidden beneath the other. The eggs were yellow, opaque, from 3.5 to 4 millimeters in diameter, about 500 of them held together in a round mass by an adhesive jelly.

Family UMBRIDÆ, Mud minnows

32. Umbra limi (Kirtland). Mud minnow.

RECORD OF CAPTURE

The mud minnow is sometimes found in weedy bays of Lake Erie, but is more common in the sluggish, weedy tributaries and near-by ponds.

DESCRIPTION

The mud minnow is most readily distinguished from the true minnows (Cyprinidæ) by its rounded caudal fin.

24.75 millimeter stage.—Total length, 24.75; standard length, 20.5; length to vent 14.0; length of head, 7.25; greatest depth, 4.75; eye, 2.0 millimeters. Cycloid scales in lateral line, 18 plus 17 = 35. Dorsal, 14; anal, 10 (rudimentary) spine before both dorsal and anal); pectorals very low, rounded, rather small; ventrals, 6, much posterior to pectorals, inserted very slightly before dorsal; caudal, rounded. Distinguished by short, oblong body, rounded tail, and black bar at base of caudal. Mouth terminal, lower jaw slightly projecting; no lateral line.

Pigmentation.—The body is well covered with very small gray chromatophores, except on ventral surface from behind head to vent. Top of head, dorsal ridge, and ventral ridge from vent to caudal are especially dark. A very dark spot occurs at base of caudal and all fins are marked.

Family ESOCIDÆ, Pickerels

33. Esox lucius Linnaeus. Pickerel, northern pike. [*Esox lucius americanus* (Gmelin). Jordan, Evermann, Clark, p. 173.]

RECORD OF CAPTURE

The pickerel is not taken in Lake Erie except at the mouths of certain creeks, but is common in the larger streams among weeds.

DESCRIPTION

The pickerels will not be confused with other genera because of their ducklike snouts. The various species are distinguished chiefly by the degree of scaliness of cheeks and opercles, a criterion which can not be used in the identification of very young specimens. However, the dorsal ray and branchiostegal counts are sufficiently different to be used as distinguishing characters.

Unfertilized egg.—Eggs stripped from a ripe female at Irving, N. Y., on April 8 measured 2.2–2.4 millimeters after expansion in water. Round, translucent, usually very slightly yellowish and often bright yellow. Surface covered with small colorless oil globules; yolk granular.

Early development.—Ehrenbaum (1911) describes and figures the larval and postlarval stages of the same pike in European waters. There the larva is 9 to 10 millimeters at hatching, with large yolk sac and inferior mouth. At 15 millimeters the lower jaw has begun to protrude, but the snout is very short. Tiny ventrals are apparent, but the wide marginal fin fold is intact. When the postlarva reaches 20 millimeters the snout is considerably lengthened, the notochord turns definitely upward, and the marginal fin fold is persistent but deeply notched. At 26 millimeters the permanent fins are formed and the young fish has a mature aspect.

Figure 67.—*Noturus flavus*, 20 millimeters

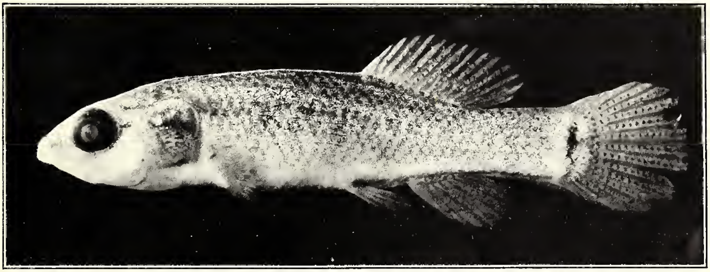

Figure 68.—*Umbra limi*, 24.75 millimeters

50.5-millimeter stage.—Total length, 50.5; standard length, 44.5; length to vent, 33.5; length of head, 16.0; depth of head, 6.0; greatest depth, 7.7; diameter of eye, 3.7 millimeters. Dorsal, 16 (last 3 not complete); anal, 16; branchiostegals, 15.

This specimen differs from a 35-millimeter muskalonge principally in its proportionately shorter snout, somewhat heavier body, dorsal and anal fin counts, and especially in number of branchiostegals (17 in muskalonge). The caudal peduncle is more slender and caudal fin not as deeply forked.

Pigmentation.—A dark band extends from tip of upper jaw through eye to posterior margin of operculum, as in the muskalonge, but the pickerel lacks the parallel band below this one, which is evident in the latter. Instead the ventro-lateral aspect of head has sparsely distributed chromatophores in 2 or 3 irregular vertical bands, radiating more or less from eye. Whereas, in the muskalonge the ventral half of body is much darker, here the dorsal half has more numerous tiny pigment spots to lateral line. From the region of ventrals backward the latter are arranged in short oblique bars, about 8 to posterior margin of dorsal, which are opposite similar darker spots below the comparatively light lateral line region, the whole

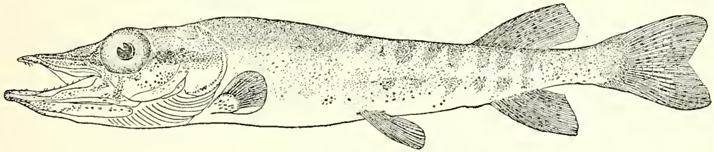

FIGURE 69.—*Esox lucius*, 50.5 millimeters

giving an obliquely striped effect. The belly is colorless with only a few chromatophores arranged along base of anal. All fins are spotted.

BREEDING

The pickerel spawns on grassy or rush beds in early spring as soon as the ice breaks up.

34. Esox masquinongy Mitchill. Muskalonge, muskallunge.

RECORD OF CAPTURE

The muskalonge occurs sparingly in weedy, sheltered spots of Lake Erie and the Niagara River. The larval specimens described here are preserved hatchery material.

DESCRIPTION

Adult muskalonge are distinguished from their near relatives the pickerels by having the lower half of the cheeks scaleless. Their branchiostegal rays number 17 to 19, whereas in the pickerels there are 11 to 16, and the dorsal rays about 17, instead of 11 to 14.

Egg.—Eggs of the Lake Chautauqua muskalonge measured 2.85 to 3.2 millimeters (usually 2.99) in diameter after preservation, with reddish-brown blastodisc. One egg taken on May 18 had an early embryo apparent with some small round black chromatophores along dorsal surface. Other eggs on May 26, however, containing embryos in a somewhat later stage, were totally colorless. The late embryo shows

the typical dark chromatophore marking seen on the ventro-lateral aspect of the newly hatched larva, and the small black pigment spots extend far out over the yolk. The incubation of muskalonge eggs requires approximately 12 to 20 days, and the yolk is absorbed in about 12 days after hatching.

11.6-millimeter stage.—Total length, 11.6; length to vent, 8.5; length of head, 1.65; snout, 0.15; diameter of eye, 0.58; greatest depth before vent, 1.95; depth behind vent, 1.55 millimeters. Myomeres, 45 to vent plus about 21+ behind. Marginal fin fold intact from shortly behind head around lophocercal caudal and

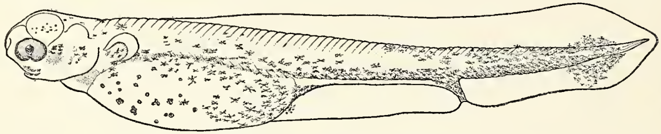

FIGURE 70.—*Esox masquinongy*, 11.6 millimeters

forward ventrally to yolk sac, with little elevation. Pectorals developed but small. Vent situated at some distance from body, at edge of marginal fin, and very evidently marked by the dark pigmentation of intestine. A large reddish yolk sac with many rather small, clear oil globules present.

Pigmentation.—The dark median band so characteristic of later stages is evident now, beginning behind eye and running over yolk sac into ventro-lateral aspect of body, which region is closely and darkly pigmented below lateral line from yolk sac almost to tip of tail. Dorsal half of body has chromatophores sparsely distributed before vent but more numerous behind, extending out on marginal fin fold above and below in caudal region. The eye is darkly pigmented. Many stellate chromatophores occur over top of yolk sac.

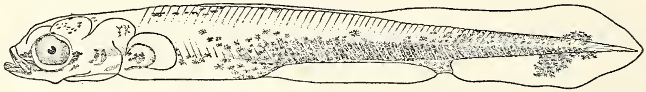

FIGURE 71.—*Esox masquinongy*, 13.9 millimeters

13.9-millimeter stage.—Total length, 13.9; length to vent, 9.4; length of head, 2.7; snout, 0.55; diameter of eye, 0.73; greatest depth before vent, 1.65; depth behind vent, 1.8 millimeters. Myomeres, 45 to vent plus 23 behind. Marginal fin reduced, especially dorsally anterior to vent; pectorals larger but unrayed; notochord straight. Although the yolk is not entirely absorbed in this stage, radical changes are occurring in the development of head. Snout longer, and profile behind tip of upper jaw slightly concave to its highest point at anterior margin of eye; lower jaw projecting; maxillary to just beyond anterior margin of eye. Vent still at ventral margin of embryonic fin fold. A few globules on ventral aspect constitute the only remaining oil in the yolk.

Pigmentation.—Chromatophore grouping is essentially as in the 11.6-millimeter stage. The lateral pigment band now starts at tip of jaws, and extends below the surface over cheeks. The chromatophores through the body region are arranged more in oblique series covering each myomere.

14.0-millimeter stage.—Total length, 14.0; length to vent, 9.4; length of head, 3.2; snout, 0.76; maxilla, 0.87; diameter of eye, 0.85; greatest depth before vent, 1.75; depth behind vent, 1.9 millimeters. Myomeres, 45 to vent plus 23 behind. Marginal fin intact, caudal lophocercal. The greatest change from the preceding stage lies in the gradual lengthening of snout.

Pigmentation.—About as the preceding stage.

15.0-millimeter stage.—Total length, 15.0; length to vent, 10.5; length of head, 3.3; snout, 0.85; diameter of eye, 0.88; maxilla, 1.8; greatest depth before vent, 1.7;

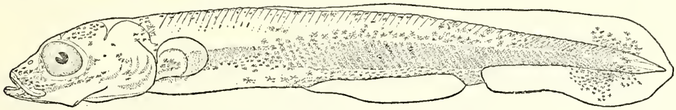

FIGURE 72.—*Esox masquinongy*, 14.0 millimeters

depth behind vent, 1.75 millimeters. Myomeres, 46 to vent plus 26 behind. Marginal fin reduced anteriorly, only slightly notched at peduncle, and still apparent before vent. Further lengthening of snout and jaws constitute the greatest change.

Pigmentation.—Unchanged from preceding except for slightly increased number of chromatophores over dorsal aspect.

33.8-millimeter stage.—Total length, 33.8; standard length, 31.2; length of head, 11.5; snout, 5.0; eye, 2.0; greatest depth before vent, 4.0; depth behind vent, 3.1 millimeters. Characterized by very much produced snout with lower jaw strongly projecting; mouth very large with maxilla extending almost to posterior margin of eye; eye large; formidable teeth on jaws, tongue, roof of mouth, pharynx, and gill arches. Marginal fin still apparent from middle of stomach to ventrals, thence to anal. Dorsal 17 (in stained and cleared specimen, elements of 3 more); anal 16 (with

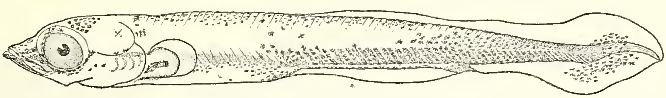

FIGURE 73.—*Esox masquinongy*, 15.0 millimeters

2 more in stained specimen); branchiostegals 17; vertebrae about 43 plus 21 (not completely ossified).

Pigmentation.—This specimen is characterized by a dark band as in younger stages from tip of snout through center of eye to posterior margin of operculum. A second band parallel to this extends from tip of lower jaw straight across head, touching the lower margin of eye without greatly diminishing its width, and terminating shortly behind eye. Top of head and dorsal aspect to lateral line are quite closely peppered with small round black chromatophores, becoming few only at base of middle third of dorsal. Below lateral line in trunk region and the whole tail have become thickly covered with larger stellate spots interspersed among small ones Base of anal and fin itself, and posterior margin of caudal, are without pigment.

BREEDING

The muskalonge is reported to start spawning in normal years a few days after the ice disappears and to continue until the latter part of April in shallow, muddy water from 10 to 15 feet deep, usually where logs and dead branches clog the bottom.

Family CYPRINODONTIDÆ, Killifishes

35. Fundulus diaphanus menona Jordan & Copeland. Barred killifish; grayback minnow. [*Zygonectus diaphanus menona* (Jordan & Copeland). Jordan, Evermann, Clark, p. 178.]

RECORD OF CAPTURE

The barred killifish is not abundant in Lake Erie, but can be found in sheltered bays and water only a few inches deep in the upper Niagara River. The specimens described were taken off Crescent Beach on June 29, 1929, in water 3 feet deep.

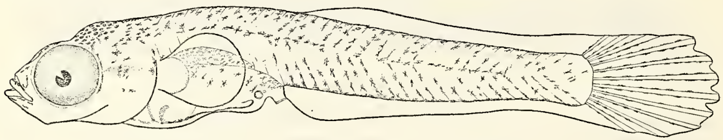

FIGURE 74.—*Fundulus diaphanus menona*, 7.1 millimeters

DESCRIPTION

The stout body and rounded caudal of the young killifish suggest *Umbra limi*, but they differ in having dorsal and anal fins inserted only slightly behind middle of body, whereas in the mud minnow the dorsal is well behind the middle and the short anal is on the last third of the body.

7.1-millimeter stage.—Total length, 7.1; standard length, 6.0; length to vent, 2.8; length of head, 1.6; snout, 0.25; diameter of eye, 0.7 greatest depth before vent, 1.1; depth behind vent, 1.0 millimeters. Myomeres, 10 to vent plus 22 behind. Low dorsal marginal fin fold originates at about thirteenth myomere behind head, continuing

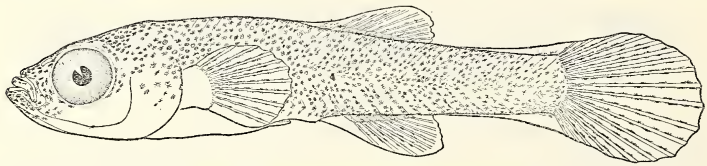

FIGURE 75.—*Fundulus diaphanus menona*, 12.3 millimeters

without a notch at peduncle into heterocercal, rayed tail; distal end of caudal notched between rays; ventral marginal identical with dorsal, originating at vent.

Pigmentation.—Chromatophores are distributed over whole body, especially on top of head and in irregular series on dorsal and ventral ridges. Lateral chromatophores are very stellate, delicate, more numerous along lateral line and distributed along line of each myotome. Much heavy pigment occurs at isthmus, continuing along mid-ventral line of stomach. There are a few chromatophores on unrayed pectorals, and the margin of each caudal ray is pigmented.

12.3-millimeter stage.—Total length, 12.3; standard length, 11.1; length to vent, 5.8; length of head, 3.4; snout, 0.75; diameter of eye, 1.1; greatest depth before vent, 2.2; depth behind vent, 1.8 millimeters. Myomeres, 10 to vent plus 20 to 22 behind.

Dorsal about 10, incompletely formed; anal about 9, incompletely formed; marginal fin fold gone; caudal fully rounded, as adult; pectorals large, rays reaching to ventrals; ventrals budding shortly before vent. Differs from preceding stage in comparatively smaller eye longer snout, more superior mouth, longer lower jaw.

Pigmentation.—Chromatophores have increased in number so that the body is quite evenly covered with stellate chromatophores, except beneath the stomach. Dorsal, anal, and pectorals have chromatophores arranged along rays, similar to caudal.

BREEDING

The barred killifish apparently breeds in June locally. No data are available concerning the duration of the breeding season, but in the Chesapeake Bay region it is reported to spawn from April until September. At mating time the males are olive-colored with about 20 pearly-white or silvery crossbars.

Family PERSOPSIDÆ, Trout-perches

36. Percopsis omiscomaycus (Walbaum). Trout-perch.

RECORD OF CAPTURE

Although young ranging from 6 to 35 millimeters were taken frequently at the eastern end of the lake from June 12 to August 10, 1928, usually near shore in water

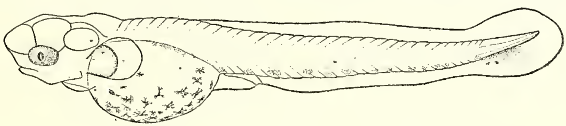

FIGURE 76.—*Percopsis omiscomaycus*, immediately after hatching, 6 millimeters

less than 20 meters deep, only a few under 8.4 millimeters were taken during 1929, on one occasion near Fairport, Ohio, on July 12, and again off Rondeau, Ontario, on the following day. At the western extremity of the lake, however, in 1929 a ripe female was taken on May 6 and eggs of this species were abundant in the tow on that date and at intervals until June 7. The only larva was taken in this region on June 29. It measured 6.5 millimeters. The trout-perch is one of the commonest Lake Erie species, being distributed in rather deep water except during the breeding season.

DESCRIPTION

The large head, deep short body, and especially the small number of myomeres (13 plus 15) make the young of this species easily distinguishable from others.

Eggs.—Freshly spawned eggs measured 1.36 to 1.85 millimeters, and contained much oil distributed in numerous globules in unfertilized specimens, but usually mingled into one large globule up to 0.7 millimeters in diameter after fertilization.

Newly hatched larva.—Total length, 6.0; length to vent, 3.0; greatest depth, 1.1; diameter of eye, 0.5 millimeters. Myomeres, 13 to vent plus 21 behind. Characterized by much-prolonged, pointed snout, with rather small, inferior mouth; small, oval eye much lower than in adult, and later developmental stages showing a gradual movement upward; snout about equal to eye. Embryonic marginal fin

originating over seventh or eighth myomere, rather low and even to lophocercal tail, thence forward to yolk sac past vent, which ends at a distance from body at edge of fin fold; pectorals developed but small, unrayed, inconspicuous, held tightly against yolk sac.

Pigmentation.—There are no dorsal or lateral chromatophores, but many large, black, stellate ones occur over ventral and lateral aspects of the yolk sac, and a row of 15 along ventral edge of myomeres from behind yolk sac to end of tail.

6.0-millimeter stage (somewhat older than preceding).—Total length, 6.0; length to vent, 3.0; greatest depth, 1.15; diameter of eye, 0.5 millimeters. Myomeres, 13 to vent plus 21 behind. Total length identical with the newly hatched specimen, but yolk sac greatly reduced and body much heavier behind vent; a single-chambered air bladder evident, covered with subsurface chromatophores.

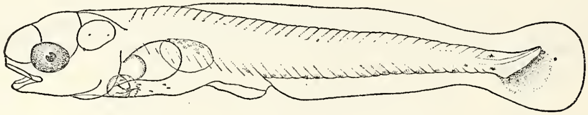

FIGURE 77.—*Percopsis omiscomaycus*, 7 millimeters

Pigmentation.—Essentially as before.

7.0-millimeter stage.—Total length, 7.0; length to vent, 3.4; greatest depth, 1.1 diameter of eye, 0.5 millimeter. Myomeres, 13 to vent plus 21 behind. Snout still somewhat decurved and mouth inferior; marginal fin unchanged; pectorals larger.

Pigmentation.—The 7-millimeter specimen is characterized by a very few large stellate chromatophores situated in the antero-ventral part of stomach region, extending up only on the right side. This unsymmetry is constant and apparently due to uneven development of this region. A ventral line of small chromatophores extends backward from anus, and a subsurface group over the stomach constitutes the only other marking.

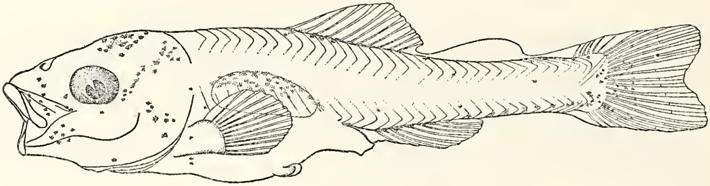

FIGURE 78.—*Percopsis omiscomaycus*, 9.5 millimeters

9.5-millimeter stage.—Total length, 9.5; standard length, 8.1; length to vent, 5.0; greatest depth, 2.0; diameter of eye, 0.8 millimeter. Myomeres, 14 to vent plus 20 behind. Characterized by long head with long, pointed snout; mouth moderate with delicate teeth in both jaws; body not compressed; air bladder large, one chambered. Eleven dorsal rays developed extending shortly beyond vent, and large portion of embryonic marginal fin fold persistent behind; anal incomplete with eight rays developed, originating below and just before end of dorsal; ventrals apparent for first time, inserted below dorsal origin; caudal forked. Eye higher than in preceding stages.

Pigmentation.—A few chromatophores occur around jaws and over top of head, a few on cheeks and below angle of jaws, very few on underside between gills, many over top of air bladder, very few on either side of dorsal fin, a double series around anal fin, and a single series of about 20 small, uneven spots from anal to end of body. A few chromatophores appear also at base of caudal and on the fin itself.

Young adult, 39.5-millimeter stage.—Dorsal II, 9 (first 2 spines very weak, represent unsegmented rays); adipose fin present; anal I, 7; ventrals 1, 8 (spine rudimentary). Total length, 35.5; standard length, 28.0; length to vent, 17.0; length of head, 9.0; greatest depth, 6.9; length to origin of dorsal, 13.5; diameter of eye, 2.5 millimeters. Myomeres, 15 to vent plus 19 behind. Body moderately elongate, somewhat compressed; caudal peduncle long and slender; head conical, pointed; mouth small, horizontal; maxillary short, narrow, no supplemental bone, not reaching eye; very small teeth in bands on premaxillaries and mandible. Dorsal short, median, and anal origin about opposite end of dorsal. Fully scaled. (Scales not shown in fig. 79.)

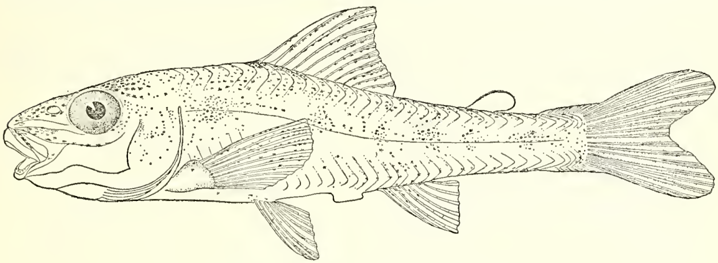

FIGURE 79.—*Percopsis omiscomaycus*, 35.5 millimeters

Pigmentation.—Many chromatophores occur over whole body, arranged laterally in about six indefinite bands. All fins except adipose are marked.

BREEDING

Adults live usually in rather deep water but spawning occurs inshore between early May and the first half of July; its height probably occurs around the middle of June.

Family SERRANIDÆ, Sea basses

37. Lepibema chrysops (Rafinesque). White bass, silver bass.

RECORD OF CAPTURE

Young white bass showing adult characters are fairly common in Lake Erie near the mouths of creeks, and larvæ from 3.7 to 13.5 millimeters were taken quite abundantly at the western end of the lake on June 29, 1929. Adults are common in the Niagara River, the lake, and at the mouths of its tributaries.

DESCRIPTION

The very large mouth, deep compressed body, and few myomeres distinguish the white bass from other Lake Erie larvæ.

5.0-millimeter stage.—Total length, 5.0; standard length, 4.8; length to vent, 2.4; length of head, 1.0; diameter of eye, 0.27; greatest depth before vent, 1.0; depth behind vent, 0.45 millimeter. Myomeres, 8 to vent plus 15 to 18 behind. Head small, mouth very large; body extremely deep and compressed. Some of yolk re-

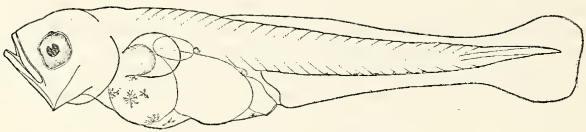

FIGURE 80.—*Lepibema chrysops*, 5 millimeters

maining, but even in this small specimen the large, short intestine already beginning to coil; oil diffused through yolk region. Marginal fin fold originating over middle of yolk region, low, continuing around tail; deeper at vent; caudal lophocercal; pectorals short and rounded.

Pigmentation.—Chromatophores are very large on ventral and lateral aspects in anterior part of stomach region, and 1 or 2 occur shortly before the vent. The

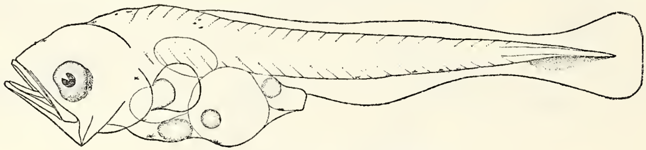

FIGURE 81.—*Lepibema chrysops*, 5.1 millimeters

only other pigmentation consists of a series of about 6 small chromatophores along ventral line of tail.

5.1-millimeter stage.—Total length, 5.1; standard length, 4.5; length to vent, 2.25; length of head, 1.1; diameter of eye, 0.3; greatest depth before vent, 1.2; depth behind vent, 0.36 millimeter. Myomeres, 8 to vent plus 15 behind. A slightly later stage than preceding, although the length is practically the same. Differs from the pre-

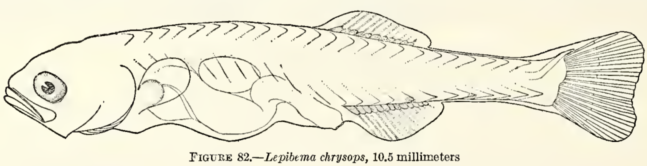

FIGURE 82.—*Lepibema chrysops*, 10.5 millimeters

ceding stage principally in the deeper body. Yolk more nearly but not completely absorbed.

Pigmentation.—Chromatophore marking is identical with preceding stage except for a very few small additional dorsal spots.

10.5-millimeter stage.—Total length, 10.5; standard length, 9.0; length to vent, 5.5; length of head, 2.0; diameter of eye, 0.6; greatest depth before vent, 2.0; depth behind vent, 1.2 millimeters. Myomeres, 8 to vent plus 15 behind. Basal elements

and incomplete rays, about 11 dorsal and 12 anal. Young fish beginning to resemble adult at this stage. Very large mouth, projecting lower jaw. No trace of ventrals or first dorsal. Air bladder present, small, adherent to dorsal wall of abdomen.

Pigmentation.—Characteristic pigment is the set of 1 or 2 very large subsurface spots near ventral margin of tail. In this specimen one is above and one just follows anal base.

12.6-millimeter stage.—Total length, 12.6; standard length, 10.5; length to vent, 6.55; length of head, 3.15; diameter of eye, 0.85; greatest depth before vent, 2.45; depth behind vent, 1.7; length to dorsal, 6.5; to anal, 6.6 millimeters. Myomeres, 12 or 13 before vent plus 13 behind. Generally as preceding stage but with arched back resembling adult. Teeth visible in lower jaw; small ventrals below and shortly behind pectorals; second dorsal I, 14; anal III, 12; slight marginal fin fold before second dorsal indicating position of first dorsal.

Pigmentation.—The marking is confined to two large subsurface chromatophores on ventral margin as before.

18.5-millimeter stage.—Total length, 18.5; standard length, 15.6; length to vent, 8.6; length of head, 5.1; snout, 1.5; diameter of eye, 1.9; greatest depth 4.4 (at vent);

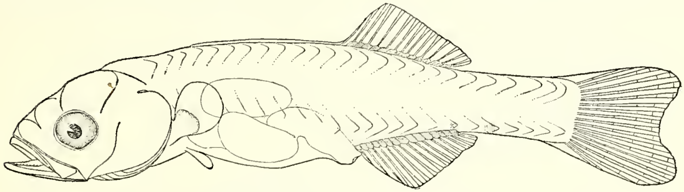

FIGURE 83.—*Lepibema chrysops*, 12.6 millimeters

length to first dorsal, 6.2; to anal, 9.0 millimeters. Body not as oblong as adult but greatly elevated and compressed; head somewhat depressed above eye; eye about equal to snout; lower jaw projecting. Dorsals IX, I, 14; anal III, 11 to 12. Vertebrae, 12 to vent plus 17 behind.

Pigmentation.—The body is colorless with sparsely distributed small black chromatophores arranged about jaws, over snout and more heavily on posterior part of head, a few on cheeks, and in a double line below second dorsal continuous to caudal (numbering about 18). A single linear series occurs along lateral line below dorsal series, and the ventral half of body has light-colored, stellate ones along the myocommata. A well-marked series on either side of anal base continues as a single series on ventral ridge to caudal. Few chromatophores are apparent on ventrals and pectorals, but the other fins are thickly covered.

BREEDING

The white bass spawns in May and June in shallow water far inshore or at the mouths of creeks.

Family PERCIDÆ, Perches

38. Perca flavescens (Mitchill). Yellow perch.

RECORD OF CAPTURE

Young of this very common Lake Erie species were taken abundantly during the middle of July, 1928, from Bertie Bay on the Canadian shore to Angola in Helgoland and meter-net towings from 0 to 4 meters below the surface, and again in the middle of July a few were captured off Silver Creek. From June 7 to August 6, 1929, great numbers of larvæ and postlarvæ were taken throughout the length of Lake Erie, usually inshore in shallow water but sometines even in the very center of the lake. So numerous were they off Rondeau in 19 meters of water on June 17, that 118 were taken in a 5-minute meter-net towing at 1 meter above the bottom. A fully developed young fish, 50 millimeters long, was taken on August 6 on the bottom at 11 meters depth.

DESCRIPTION

The rounded head, large rounded yolk sac with one large oil globule, and pigment which spreads from the ventral ridge up a short distance along the myocommata are

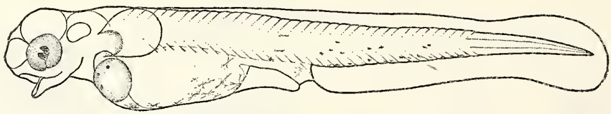

FIGURE 84.—*Perca flavescens*, 5.6 millimeters

constant early larval characters, and the serrated preopercle, lack of canine teeth, oblong compressed body with ventrals close together distinguish the later stages.

Egg.—The eggs of the yellow perch are spawned in a long tube-shaped mass, closed at the ends and folded like the bellows of an accordion. The mass contracts to a length of less than a foot through this folding, but can be stretched out 3 or 4 times as long. Such a mass was spawned in the Buffalo Musem Aquarium on May 26, 1930, but inability to procure a ripe male made embryological study impossible.

5.6-millimeter stage.—Total length, 5.6; length to vent, 2.75; length of head, 0.75; snout, 0.17; diameter of eye, 0.32; greatest depth before vent, 0.93; depth behind vent, 0.75 millimeters. Myomeres, 18 to vent plus 18 behind (incomplete). Characterized by large yolk sac with one large clear yellow oil globule, about 0.4 millimeter in diameter, placed anteriorly; embryonic marginal fin fold granular in texture, originating dorsally at base of brain and ventrally at middle of yolk sac, moderate in height without pronounced elevation; pectorals well developed.

Pigmentation.—The eye is very dark. Sparsely distributed large light-colored stellate chromatophores occur on bottom of yolk sac and usually one or more on dorsal and ventral aspects of intestine. An uneven series of very small unequal chromatophores is evident ventrally behind the vent, and the divisions of the myomeres (few or all depending on the individual) are marked by black pigment lines running from ventral edge to lateral line.

7.3-millimeter stage.—Total length, 7.3; length to vent, 3.6; greatest depth, 0.95; diameter of eye, 0.45 millimeter. Mouth terminal, slightly below mid-line; yolk much absorbed with one large, oval, yellowish oil globule occupying the anterior part;

vent ending far from body at edge of marginal fin. Pectorals considerably larger; dorsal embryonic marginal fin fold raised somewhat before the vent, dropping again about midway from vent to end of myomeres; ventral marginal similarly elevated just behind the vent; caudal lophocercal.

Pigmentation.—Chromatophores occur on underside of yolk in a very irregular double row, fewer and smaller than in the preceding stage. There is a single row of

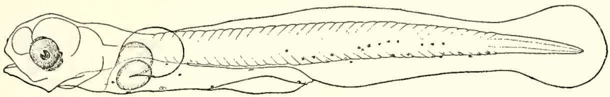

FIGURE 85.—*Perca flavescens*, 7.3 millimeters

about 15 very tiny ones on ventral aspect behind vent, and, extending upward from it a short way over the sides, are a series of from 1 to 3 small chromatophores between each myomere. Two chromatophores appear on intestine at vent.

8.25-millimeter stage.—Yolk completely absorbed, and simple intestine evident. Fins and chromatophores as before.

9.0-millimeter stage.—Total length, 9.0; length to vent, 5.0; greatest depth, 1.04; diameter of eye, 0.5 millimeter. This and successive stages changing mostly in

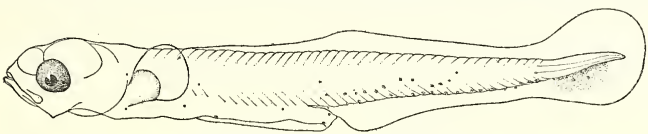

FIGURE 86.—*Perca flavescens*, 9 millimeters

development of head and heavier body. Pigmentation remains the same, consisting of a single ventral series from vent backward, and an irregular line on either side of body midway between ventral ridge and lateral line.

12.5-millimeter stage.—Total length, 12.5; standard length, 12.0; length to vent, 6.2; greatest depth, 2.1; diameter of eye, 0.6 millimeter. Stomach region prominent showing coiled intestine; head more pointed. Marginal fin fold intact but dorsal portion elevated and small elements of 7 rays starting immediately above vent, one

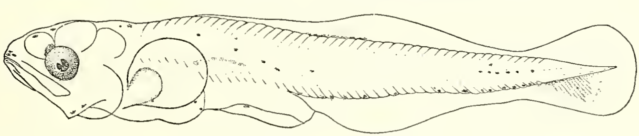

FIGURE 87.—*Perca flavescens*, 12.5 millimeters

for each myomere; in other specimens of this length, a cell concentration indicating later location of anal; few rays on ventral part of caudal but still lophocercal; pectorals moderate.

Pigmentation.—A few chromatophores are developed around both jaws and top of head, a few on preopercle, a subsurface group over stomach region, and 1 very large chromatophore on ventral aspect midway to vent. The lateral and ventral series of 17 to 25 are about as before.

14.4-millimeter stage.—Total length, 14.4; standard length, 12.9.; length to vent, 7.5; length of head, 3.45; snout, 0.9; diameter of eye, 0.8; greatest depth before vent, 2.5; depth behind vent, 2.0 millimeters. Myomeres, 22 to vent plus 18 behind. About 12 very tiny spines of first dorsal apparent, 15 elements and 13 partly formed rays of second dorsal rays; anal I, 8, incomplete; caudal rays developed, distal end of caudal emarginate; ventrals budding.

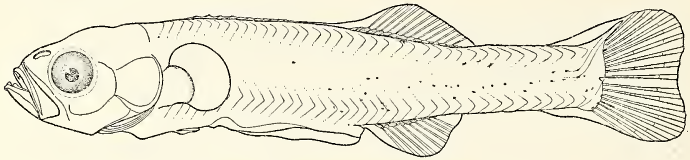

FIGURE 88.—*Perca flavescens,* 14.4 millimeters

Pigmentation.—The marking is much as in preceding stages, but the chromatophores are inclined to be lighter with the ventral series less conspicuous or entirely lacking.

20.0-millimeter stage.—Total length, 20.0; standard length, 17.0; length to vent, 10.5; length of head, 4.7; snout, 1.0; diameter of eye, 1.55; greatest depth before vent, 3.95; depth behind vent, 3.2; length to first dorsal, 6.1; to second dorsal, 10.3; to anal, 11.0 millimeters. Myomeres, 24 to vent plus 16+ behind. At this length the young fish resembles the adult with all fins formed, serrated preopercle, and large mouth. Dorsal XV, II, 13; anal II, 8.

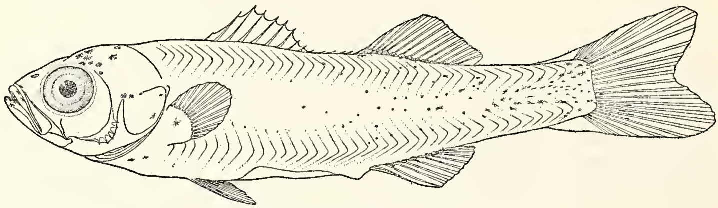

FIGURE 89.—*Perca flavescens,* 20 millimeters

Pigmentation.—This specimen is sparingly marked, with chromatophores limited to a few large stellate ones on jaws and over head, a few at dorsal and anal bases, and others distributed over sides of tail from vent backward, extending somewhat on to caudal. The anterior half of body from behind head to region of vent is almost colorless.

For comparison with the previous stage described the following heavily pigmented specimen is included. It is in a slightly older stage of development evidenced by the longer snout, larger mouth, and more advanced fins, although barely larger than the other.

Postlarva, 20.5-millimeter stage.—Dorsal III to VII–II, 9 to 12 (badly mutilated); anal II, 6 to 8; caudal shallowly forked; ventrals developed, below pectorals. Total length, 20.5; standard length, 17.25; length to vent, 10.5; length to first dorsal, 5.95; length of maxillary, 2.0; greatest depth, 3.6; diameter of eye, 1.5 millimeters. Myo-

meres about 18 before vent plus 18 behind. Body greatly compressed, more elongate than adult yellow perch but decidedly deeper than pike perch of this length; mouth large, with very small sharp teeth discernible but no canines, maxillary reaching to middle of eye; pelvic fins very close together.

Pigmentation.—Round and stellate chromatophores occur on head and a double line dorsally to end of body. Others are scattered also over sides of head and more or less evenly over sides of body. Many specimens have a dark subsurface area over stomach region. A rather indistinct ventral row of large stellate chromatophores extends to vent and an irregular double series from vent to caudal, darkest at base of anal. Dorsals, anal, and caudal are speckled. The banded coloration of the adult is not evident in these preserved specimens.

Adult.—Specimens of 40 millimeters fully developed, definitely banded.

BREEDING

Our records of young from Lake Erie show that hatching may occur as early as the first week of May and continue until after the first week of July, but the height of the season in 1928 and 1929 at both ends of the lake was between June 7 and 17.

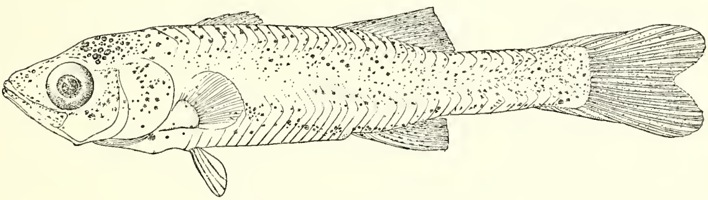

FIGURE 90.—*Perca flavescens*, 20.5 millimeters

39. Stizostedion canadense griseum (DeKay). Sauger; sand pike. [*Cynoperca canadensis* (Smith). Jordan, Evermann, Clark, p. 282.]

RECORD OF CAPTURE

Only one postlarval sauger was captured during the two seasons work of the *Shearwater*, a 14.5-millimeter specimen at 60 meters in the deep hole off Long Point Bay on July 30, 1928. Several young of about 28 to 30 millimeters were taken on June 29, 1929, in towings near the surface at the western end of the lake, and others of this size in seinings at the mouths of creeks. The adults are common in Lake Erie, seeking shallow water rather than the deeper parts.

DESCRIPTION

The earliest larva is distinguished from that of *Perca flavescens* by the larger number of myomeres, and the postlarva by its slenderer, less compressed body, larger mouth, and the characteristic fin-ray count of the adult, dorsal XII to XIII-I, 17 to 18; anal II, 12.

9.0-millimeter stage.—Total length, 9.0; standard length, 8.8; length to vent, 4.25; length of head, 1.8; diameter of eye, 0.47; greatest depth before vent, 1.45; depth behind vent, 0.65 millimeter. Myomeres, 16 to vent plus 26 behind (incomplete). Dorsal marginal fin fold originating shortly behind head, rising to highest point beyond

vent, continous around lophocercal tail (in which concentration ventrally already indicates formation of caudal rays), and corresponding to dorsal contour on the ventral side. Mouth large, maxilla to posterior margin of pupil; both jaws armed with canine teeth.

Pigmentation.—The marking is confined to one large chromatophore on ventral side about halfway from pectoral base to vent, and a few barely distinguishable on dorsal aspect of air bladder.

13.0-millimeter stage.—Total length, 13.0; standard length, 12.5; length to vent, 6.5; length of head, 2.8; diameter of eye, 0.68; greatest depth before vent, 2.5; depth

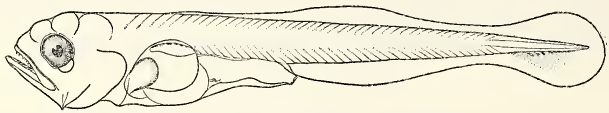

FIGURE 91.—*Stizostedion canadense griseum*, 9 millimeters

behind vent, 1.4 millimeters. Myomeres, 17 to vent plus 27 behind (incomplete). Snout lengthening and becoming pointed (differing from *Perca* in this respect) with well developed canines evident; mouth terminal. Marginal fin fold abruptly elevated immediately behind vent over the basal elements of about 15 rays; persisting ventrally with basal elements and suggestions of about 11 rays; caudal becoming heterocercal, its lower rays developed. Large simple air bladder; intestine coiled; vent open, intestine ending away from body, at edge of marginal fin.

14.6-millimeter stage.—Dorsal XIII–I, 15 (incomplete); anal II, 10 (incomplete); pectorals rather small; ventrals small, below pectorals; caudal emarginate. Total length, 14.6; standard length, 12.6; length to vent, 7.7; greatest depth, 2.0; diameter of eye, 1.0 millimeter. Myomeres, 21 to vent plus 21 behind. Body elongate, dorsal

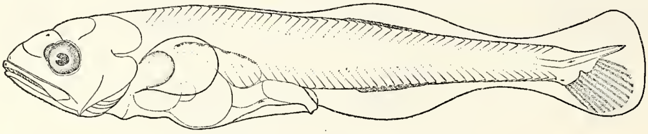

FIGURE 92.—*Stizostedion canadense griseum*, 13 millimeters

contour slightly depressed before soft dorsal and anal, and somewhat depressed just behind head; head pointed, sides quite parallel, eyes directed sideward; mouth terminal; large curved teeth in both jaws; maxillary reaching to posterior margin of pupil. First dorsal, consisting of 13 slender spines, originating just behind ventrals.

Pigmentation.—The 14.6-millimeter specimen is mostly opaque white. One large chromatophore is apparent on dorsal side of intestine at vent, and a double ventral series of about 25 small, uneven, inconspicuous pigment spots (12 of them around anal) extends from vent to end of body. A few occur in the thoracic region and near the posterior limit of lateral line.

27.0-millimeter stage.—Total length, 27.0; standard length, 22.0; length to vent, 13.8; length of head, 7.7; snout, 2.0; diameter of eye, 2.0; greatest depth before vent,

4.1; depth behind vent, 3.15; length to dorsal, 8.0; to anal, 14.1 millimeters. Myomeres, about 22 to vent plus 19 behind (incomplete). Snout greatly produced and pointed, jaws equal; maxilla to hind margin of pupil; canines large; body elongate and terete. Dorsal XII–I, 18; anal II, 12; ventrals well developed, inserted before vertical from first dorsal spine; dorsals well separated; caudal deeply forked.

Pigmentation.—Chromatophores are massed over tip of both jaws, top of head especially behind eye, and on operculum. A double series occurs on dorsal aspect

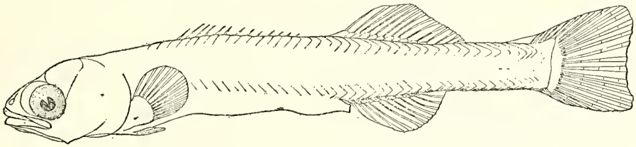

FIGURE 93.—*Stizostedion canadense griseum*, 14.6 millimeters

of body, heaviest about bases of fins, and a double series around anal base followed by a single series behind to caudal. There are a few tiny chromatophores on the sides of the caudal peduncle and along the lateral line in this region. All fins are unmarked except for a few chromatophores outlining the caudal base.

39.0-millimeter stage.—Total length, 39.0; standard length, 33.0; length to vent, 20.05; length of head, 10.5; snout, 4.5; diameter of eye, 2.9; greatest depth before vent, 6.1; depth behind vent, 5.0; length to first dorsal, 12.0; to anal, 11.2 millimeters. Body rather slender, not much compressed, subterete; head pointed with maxilla

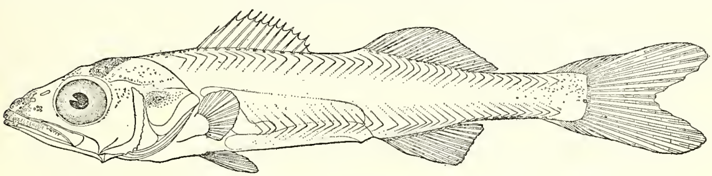

FIGURE 94.—*Stizostedion canadense griseum*, 27 millimeters

reaching to hind margin of pupil only; dorsals well separated. Dorsal XIII–I, 17; anal II, 12.

Pigmentation.—The 39-millimeter fish is white with numerous black chromatophores covering all of body, most numerous on both jaws and over top of head. A slightly larger single series occurs at base of each marginal fin and along the lateral line posterior to the dorsals. The belly is white. The caudal is the only fin with many chromatophores.

BREEDING

The sauger spawns in early spring on shallow gravelly or sandy bars, often running up rivers. With the beginning of warm weather it is reported to work its way downstream again and off into deep water. Whether the postlarval stages are common also in deep water, or whether this specimen was an exception, can not be determined from our scanty evidence.

40. Stizostedion vitreum (Mitchell). Yellow pike, pike-perch, wall-eyed pike.

RECORD OF CAPTURE

Larval *Stizostedion*, probably of this species, were taken in towings in the western part of the lake from the middle of May until the middle of June. It is a very common fish of Lake Erie and the Niagara River and the young may be seined in abundance alongshore in sheltered places.

DESCRIPTION

The larval yellow pike resembles the yellow perch but has a myomere count of 15 plus 26 instead of 18 plus 18. Postlarvæ and young stages may be distinguished

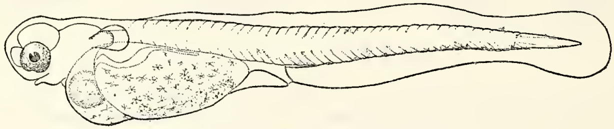

FIGURE 95.—*Stizostedion vitreum*, 7.75 millimeters

from the yellow perch by their slenderer, more rounded bodies, and the possession of canine teeth, and from the young of the more closely related sauger by a soft dorsal count of 19 to 22 rather than 17 to 19.

Newly hatched larva (Thurlow hatchery specimen identified and loaned by John Hart).—Total length, 7.75; length to vent, 3.7; greatest depth, 1.5; diameter of eye, 0.5 millimeter. Myomeres, 15 to vent plus 26 behind (incomplete). Inferior mouth and vent open; yolk very large, bright yellow in color and covered completely by large, light-colored, very stellate chromatophores, which extend over the heart and the large

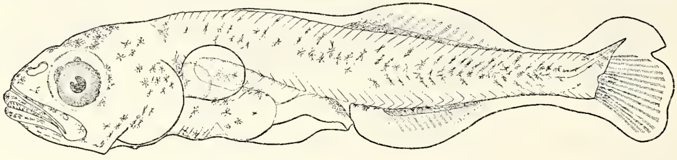

FIGURE 96.—*Stizostedion vitreum*, 12.5 millimeters

clear yellow oil globule. Eye large, blue-black in color. Embryonic marginal fin fold complete; small pectorals developed.

Pigmentation.—There are about two large chromatophores on dorsal aspect of tail, and a well-defined line of dark brown spreading chromatophores, almost interlocking, from vent to caudal.

Older specimens in the same collection have the yolk absorbed. In these the large stellate yolk chromatophores persist on the yellow stomach region, and the last quarter of dorsal aspect has about 6 others arranged alternately on the two sides.

12.5-millimeter stage.—Total length, 12.5; standard length, 11.75; length to vent, 6.5; length of head, 3.35; snout, 0.9; diameter of eye, 0.8; greatest depth before vent,

2.5; depth behind vent, 2.75 millimeters. Myomeres, 21 to vent plus 25+ behind. Embryonic marginal fin fold starting dorsally shortly before vent, becoming abruptly high immediately behind over the elements and slight suggestions of about 17 rays, ventrally persisting before vent and behind over elements and suggestions of about 11 anal rays; no ventrals; pectorals moderate; rays forming in heterocercal caudal. Body rather slender, not as compressed as yellow perch of similar length. Small canines in both jaws; maxillary to hind margin of pupil. Large simple air bladder. Vent situated at distance from body, at edge of marginal fin fold.

Pigmentation.—Rather large stellate chromatophores are distributed on tips of both jaws, over top and sides of head, and in a single series on dorsal ridge, becoming double around fin. An irregular series extends along lateral line with myomere interspaces above and below marked with irregular black lines. Chromatophores have become scattered over sides of stomach and are more numerous below the surface over air bladder and intestine to vent. They occur also along ventral line, especially at base of anal, and extend on to caudal. The eye is very black.

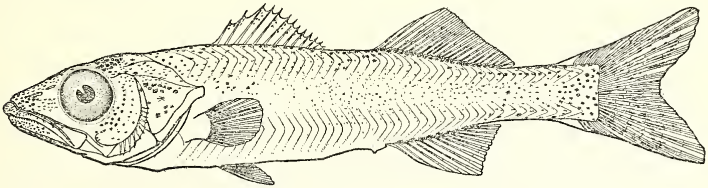

FIGURE 97.—*Stizostedion vitreum*, 32 millimeters

32.0-millimeter stage.—Total length, 32.0; standard length, 26.0; length to vent, 17.0; length of head, 9.1; snout, 2.0; diameter of eye, 1.8; maxilla, 4.0; greatest depth before vent, 5.6; depth behind vent, 4.0; length to first dorsal, 10.0; to second dorsal, 17.0; to anal, 18.0 millimeters; dorsal XIII–I, 21 (well separated); anal II, 13. Myomeres, 22 to vent plus 20 behind. Body long, of moderate depth; mouth large, maxilla to beyond pupil; preopercle serrate; canines strong.

Pigmentation.—Chromatophores are heavy over top of head and usually in about seven patches or bars crossing dorsal ridge. These patches extend only a short distance down each side of body, then are broken, and other oblique bands, starting in the interspaces, cross the lateral line and extend midway to ventral ridge. There is much individual variation in pattern, as seen in the specimen figured, which does not exhibit these bands markedly. The ventral surface is colorless except from origin of anal backward to caudal, where a double series of small, closely placed chromatophores occurs. Both dorsals and caudal are pigmented, but other fins remain colorless except for a few chromatophores at base of pectorals.

BREEDING

The yellow pike spawns in spring, running upstream as soon as the ice breaks up. It prefers sandy bars in shallow water.

41. Hadropterus maculatus (Girard). Black-sided darter. [*Alvordius maculatus* Girard. Jordan, Evermann, Clark, p. 283.]

RECORD OF CAPTURE

This rather uncommon darter is found in many of the warmer tributary streams. The single specimen represented in our collections was seined in Ellicott Creek on August 1, 1928.

DESCRIPTION

Two anal spines and nonprotractile premaxillaries are characters which the black-sided darter has in common with the log perch, separating them from other darters, but the absence of a conical projection of the snout which typifies the log perch, and vertebral count of 42 or less, distinguishes the present species.

41.0-millimeter stage.—Total length, 41.0; standard length, 35.0; length to vent, 21.5; length of head, 9.0; greatest depth, 6.4; diameter of eye, 2.6 millimeters. Myomeres, 20 to vent plus 22 behind. Dorsal XII, 13; anal II, 10; caudal only slightly emarginate; ventrals just behind pectoral base. Body elongate, fusiform; head long and pointed; mouth rather wide, subinferior, lower jaw included.

Pigmentation.—A black streak occurs on upper jaw, and a wide longitudinal stripe from tip of snout through eye to back of head. The top of head and interorbital space are heavily pigmented from occiput to dorsal fin, and the whole dorsal aspect is covered with small chromatophores gradually becoming a pattern outlining the scale arrangement. On lateral line, 5 large and 2 small patches are evident where the scales are outlined and crowded with chromatophores (lateral line practically straight, curving downward only slightly to region of vent). The dorso-lateral region is patterned like python skin, that is, the scales are outlined to make an irregular pattern of lighter and darker patches. Chromatophores occur at margin of anal and a single series a short distance behind. The ventrals are the only fins unmarked.

BREEDING

The black-sided darter spawns in spring in shallow water over a stony bottom.

42. Percina caprodes zebra (Agassiz). Log perch. [*Percina zebra* (Agassiz). Jordan, Evermann, Clark, p. 283.]

RECORD OF CAPTURE

Adults were taken in Petersen and Helgoland trawls and seines near shore during July and August, 1928. Larvæ and postlarvæ from 6 to 24 millimeters were taken in western Lake Erie from June 29 to July 3, and a single specimen 6.5 millimeters long was taken on August 20 in a bottom towing in 13 meters off Point Pelee, also in the far western section.

Although the longer intestine and other characters eliminate *Perca*, the head resembles this genus so much that *Percina*, in which the head is similar to *Perca*, is immediately suggested. In the larva the moderate subinferior mouth, sharp pointed teeth, rudimentary air bladder, and large pectorals and in later stages the subtruncate snout, which begins to be evident soon after a length of 12 millimeters is attained, are characteristic.

Figure 98.—*Hadropterus maculatus*, 41 millimeters

DESCRIPTION

6.6-millimeter stage.—Total length, 6.6; length to vent, 4.1; length of head, 1.1; snout, 0.2; diameter of eye, 0.3; greatest depth before vent, 0.83; depth behind vent, 0.87 millimeters. Myomeres, 22 to vent plus 16+ behind. Embryonic marginal fin fold originating dorsally over stomach region, rising to its highest point behind

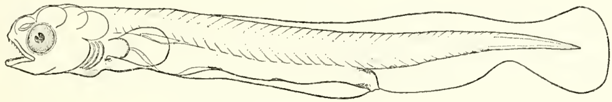

FIGURE 99.—*Percina caprodes zebra*, 6.6 millimeters

vent, continuing around lophocercal tail, and similar in contour ventrally. Body elongate, rather compressed; mouth reaching past front of pupil, armed with sharp pointed teeth in both jaws; mouth subinferior with very slight projection of snout; rudimentary air bladder; large pectorals.

Pigmentation.—One large chromatophore occurs below base of each pectoral, three along ventral margin with the last at vent, one above this on dorsal surface of intestine, and a broken inconspicuous single series on ventral ridge to caudal.

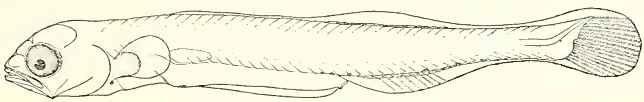

FIGURE 100.—*Percina caprodes zebra*, 12.15 millimeters

12.15-millimeter stage.—Total length, 12.15; standard length, 11.2; length to vent, 6.6; length of head, 2.06; diameter of eye, 0.6; greatest depth before vent, 1.4; depth behind vent, 0.98 millimeter. Myomeres, 20 to vent plus 20+ behind. Elements of 14 dorsal rays in marginal fin fold, and about 9 elements and 8 incomplete rays of anal directly below; tail becoming heterocercal and caudal rays forming.

Pigmentation.—The marking is as in the preceding stage with 1 subsurface chromatophore below pectoral base, 1 or more along ventral margin of intestine,

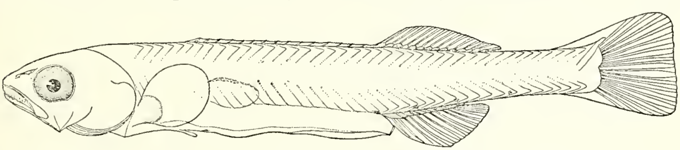

FIGURE 101.—*Percina caprodes zebra*, 14.2 millimeters

and about 4 or more large subsurface spots on ventral ridge of tail, the first of which is at vent.

14.2-millimeter stage.—Total length, 14.2; standard length, 12.6; length to vent, 8.25; length of head, 3.0; snout, 0.67; diameter of eye, 1.0; greatest depth before vent, 2.03; depth behind vent, 1.4 millimeters. Myomeres, 20 to vent plus 20+ behind. Snout pointed, definitely projecting; body elongate, slightly compressed. All spines and rays of marginal fins apparent but not completely developed, spines of first

dorsal very small; caudal barely emarginate; pectorals large but unrayed, ventrals just appearing.

Pigmentation.—The marking is unchanged from the preceding stage except for the addition of a few chromatophores over small air bladder.

20.5-millimeter stage.—Total length, 20.5; standard length, 17.0; length to vent, 10.8; length of head, 4.65; snout, 1.0; diameter of eye, 1.35; greatest depth before vent, 3.15; depth behind vent, 2.53; length to dorsal, 6.1; to anal, 11.4 millimeter. Myomeres, 22 to vent plus 20+behind. Tapering; piglike snout characteristic; mouth inferior, not as small comparatively as in adult. Fins long and low; dorsal XV, 15; anal II, 10 (last divided); ventrals well separated; pectorals rounded.

Pigmentation.—Tip of snout and both jaws have many small chromatophores. Others are scattered sparingly over eye and over head on its distal margin. There are short patches along dorsal ridge, first between the dorsals, second below middle of second dorsal, third at end of fin and fourth nearly to end of body. Two patches occur along lateral line directly below the first and fourth dorsal patches, with 1 or more chromatophores between. A double series appears along ventral ridge from vent to caudal, heavier around anal base and a few large ones at proximal end of

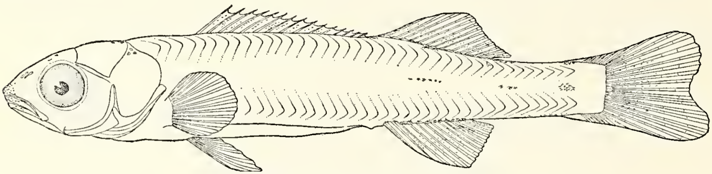

FIGURE 102.—*Percina caprodes zebra*, 20.5 millimeters

caudal rays indicate the future black spot. All vertical fins are dotted with small chromatophores, but the paired fins are colorless.

25.5-millimeter stage.—Dorsal XV, 14, well separated; anal II, 10; ventrals long, more than halfway to vent, well separated; pectorals rather large, equal to ventrals. Total length, 25.5; standard length, 21.0; length to vent, 13.5; length of head, 6.0; greatest depth, 4.0; diameter of eye, 2.0 millimeters. Myomeres, about 20 to vent plus 20 behind (slightly incomplete). Body elongate, slightly compressed; head depressed, rather pointed; horizontal mouth small and inferior, overlapped by subtruncate, piglike snout; very small, pointed teeth on vomer and palatines.

Pigmentation.—The marking is in bars, 8 crossing dorsal aspect, not connected but opposite the lateral bars, of which there are about 10. Chromatophores are scattered over jaws, top, and sides of head. A line of small black ones extends from vent to end of body, double around anal fin. Many occur on dorsals and anal in a more or less longitudinally barred pattern. The caudal is dusky with a black spot at its base.

BREEDING

This very common lake fish spawns upstream during late spring. The capture of late larval and postlarval stages off some of the creeks in late June indicates that the season extends well into that month and that some spawning probably occurs only a short distance from the creek mouths, the young being carried out into the lake soon after hatching.

43. Rheocrypta copelandi Jordan. Copeland's darter. [*Cottogaster copelandi,* (Jordan). Jordan, Evermann, Clark, p. 285.]

RECORD OF CAPTURE

Although this is a common species in Lake Erie and the larger tributaries, only one larva taken by the survey can be assigned even tentatively to it. This was a 7-millimeter specimen taken on June 7, 1929, in 12 meters near Point Abino on the Ontario shore. The fact that many adults seek streams in which to spawn probably accounts in this species, as in many others, for the scanty number of young found in the lake towings. The older specimen described below was captured at the mouth of Cattaraugus Creek in late August.

DESCRIPTION

Concerning the older stages the color pattern of many darters is so similar that it fails to be useful as a field character. However, there are certain definite differences which careful examination will disclose. In the first place, the premaxillaries of this species are protractile, distinguishing it from *Hadropterus* and *Percina,* and the mid-line of belly has a single series of enlarged, spinous scales which are lacking in *Imos-*

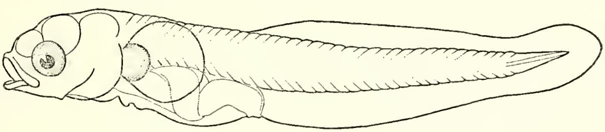

FIGURE 103.—*Rheocrypta copelandi,* 6.1 millimeters

toma and *Ammocrypta* and others. The color pattern and general characters resemble *Boleosoma* closely, but the latter has only 1 instead of 2 anal spines, its belly is covered with normal scales, and the anal fin is shorter than the second dorsal.

6.1-millimeter stage.—Total length, 6.1; length to vent, 2.6; length of head, 1.2; snout, 0.25; diameter of eye, 0.26; greatest depth before vent, 1.0; depth behind vent, 1.1 millimeters. Myomeres, 14 to vent plus 24 behind. Moderate marginal fin fold, alike above and below, originating in vent region; pectorals large, not reaching quite halfway to vent. Vent located away from body, at ventral margin of fin fold. Although traces of the yolk still are present, the intestine is large and coiled. It differs from *Lota* of like size taken simultaneously in the less deep head, smaller eye, absence of air bladder, and especially in the fewer number of myomeres in tail. *Cottus* is suggested in general shape and myomere count but it is much smaller than a sculpin of like development. The body is sturdier than in the comparatively elongate *Perca flavescens,* which species, too, is recognized by its pigment series.

Pigmentation.—The 6.1-millimeter larva is entirely colorless except for its dark eye.

43.0 millimeter stage.—Total length, 43.0; standard length, 35.8; length to vent, 22.2; length of head, 8.5; snout, 2.5; diameter of eye, 2.6; greatest depth, 6.0; length to first dorsal, 11.5; to anal, 22.4 millimeters. Vertebrae, 18 plus 20. Dorsal XI, 12; anal II, 9. Body rather slender, elongate; head large and long, resembling *Boleosoma,* with small, subinferior, horizontal mouth and protractile premaxillaries. Mid-line of belly with single series of enlarged, spinous, thickened scales.

Pigmentation.—The back is tessellated similar to *Boleosoma* and *Hadropterus* with small zebralike markings, but the brown patches along lateral line are more linear and form a lateral band, somewhat interrupted. Along dorsal ridge the brown spots are large and obvious, and a black streak extends forward from eye to snout. Very few chromatophores occur on fins, except for a small inklike spot at base of caudal, and a black spot on anterior rays of spinous dorsal.

BREEDING

Greeley (1929) took ripe males on June 11 in the riffles about a quarter of a mile from the mouth of Eighteen Mile Creek.

44. Boleosoma nigrum nigrum (Rafinesque). Johnny darter. [*Boleosoma nigrum* (Rafinesque). Jordan, Evermann, Clark, p. 287.]

RECORD OF CAPTURE

On June 11, 1928, a small mass of eggs assigned to this species was found attached to an empty clam shell caught in a torn gill net floating near Sturgeon Point.

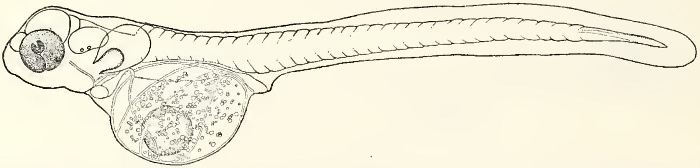

FIGURE 104.—*Boleosoma nigrum nigrum*, immediately after hatching, 5 millimeters. (Drawn from live specimen)

Between June 12 and August 8, specimens ranging from 5.5 to 35 millimeters were taken near shore between Buffalo and Dunkirk in Helgoland trawls towed at 7 to 25 meters. (Figures 105–109.) No young were taken in 1929 in the eastern part of Lake Erie but a few eggs and numerous young shortly after hatching were taken on June 29 in shallow water at the western end. Adults are commonly found in weedy places alongshore.

DESCRIPTION

The inferior mouth with characteristic protruding snout, large eye, and myomere count of 15 plus 19 to 22, distinguish the earlier stages. The protractile premaxillaries and single anal spine mark the later ones further.

Egg.—Diameter of living egg 1.4 to 1.5 millimeters, with an oil globule lying ventral to embryo in yolk; not perfectly round but flattened by adhesion to others; all with late embryos, opaque white except for black eyes.

Newly-hatched larva.—Total length, 5.0; length to vent, 2.25; diameter of eye, 0.4 millimeter. Myomeres, 11 to vent plus 22 behind (very incomplete). Large yellowish oil globule lying at ventral margin of large yolk sac; short intestine terminating just behind yolk, at margin of fin and free from body; embryonic marginal fin fold originating directly behind head, low and even around lophocercal tail; pectorals developed; colorless except for black and silvery eye.

1-day-old larva.—Length still 5.0 millimeters but yolk sac appreciably reduced.

5.6-*millimeter stage.*—Total length, 5.6; length to vent, 3.0; greatest depth, 0.8; diameter of eye, 0.4 millimeter. Myomeres, 15 to vent plus 19 behind (incomplete). Characterized by very large pectorals extending past middle of yolk region; large well-imbedded eyes; prominent snout; comparatively short intestine; moderate mouth,

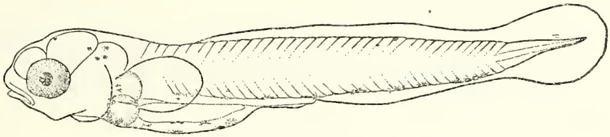

FIGURE 105.—*Boleosoma nigrum nigrum,* 5.6 millimeters

inferior, upper law projecting; dorsal contour very sloping to behind eye; yellow yolk sac much reduced with large yellow oil globule in anterior position.

Pigmentation.—The eye is very dark. About 4 lines of large stellate chromatophores occur on ventral surface of yolk sac, 4 very large subsurface spots over yolk region, the last of them immediately before vent, 4 groups (either of a single chromatophore or several) from vent to caudal and a very few on side of head.

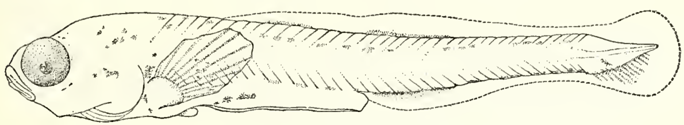

FIGURE 106.—*Boleosoma nigrum nigrum,* 7.1 millimeters

7.1-millimeter stage.—Total length, 7.1; length to vent, 4.0; greatest depth, 1.1; diameter of eye, 0.5 millimeter. Myomeres, 15 to vent plus 21 behind. General characters as preceding stage, but eye definitely higher, almost at dorsal margin with head much depressed above. Embryonic marginal fin low, intact, but slight depression above vent and concentration indicating later position of two dorsals and anal; ventrals appearing; pectorals very large; caudal lophocercal.

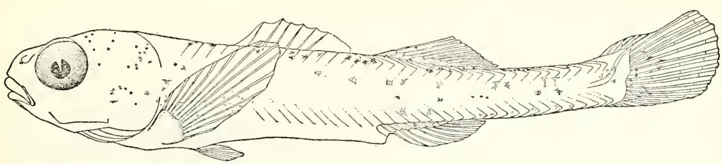

FIGURE 107.—*Boleosoma nigrum nigrum,* 9.6 millimeters

Pigmentation.—Ventral chromatophores of yolk sac are reduced to a few large masses on bottom and sides of stomach region. Four large ones occur on dorsal aspect of intestine and six on ventral edge behind vent. Others (subsurface) in this stage are evident above each ventral one, and, on the myomeres above the notochord, the whole pattern suggests that of a 15-millimeter specimen taken simultaneously.

9.6-millimeter stage.—Dorsal VI, 10 (broken and incomplete); anal I, 7. Total length, 9.6; standard length, 8.1; length to vent, 5.1; greatest depth, 1.54; diameter of eye, 0.9 millimeter. Myomeres, 15 to vent plus 22 behind. Changed from preceding principally in partial development of spines and rays; further development of ventrals and pectorals, completion of caudal, and the addition of a few scattered chromatophores over head, dorsal aspect of body, and lateral line.

15.0-millimeter stage.—Dorsal VIII, 11; anal I, 8. Total length, 15.0; standard length, 12.6; length to vent, 8.0; greatest depth, 2.45; diameter of eye, 1.1 millimeters. Myomeres, 15 to vent plus 22 behind. Adult characters apparent with completion of fins, and addition of more chromatophores on snout, head, and sides of body, giving typically blotched appearance; fins still colorless except for a few chromatophores near base of caudal.

35.0-millimeter stage.—Small adult female with ripe eggs.

BREEDING

The eggs of the Johnny darter are attached to objects usually about a foot or so below the surface of the water. The flat undersides of stones are a favorite nest, over which the parent fish guards assiduously. The breeding season is in May and June, at which time the anterior part of the male becomes very black.

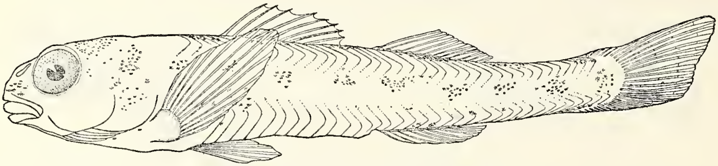

FIGURE 108.—*Boleosoma nigrum nigrum*, 15 millimeters

45. Poecilichthys coeruleus coeruleus (Storer). Rainbow darter; soldier darter; blue darter. [*Oligocephalus coeruleus* (Storer). Jordan, Evermann, Clark, p. 291.]

RECORD OF CAPTURE

The rainbow darter is never found in Lake Erie, but frequents the shallow creeks of the region, where it is common.

DESCRIPTION

Its incomplete lateral line, moderately decurved snout, and anal rays numbering 12 to 14 differentiate the rainbow from other darters of this genus.

22.6-millimeter stage.—Total length, 22.6; standard length, 19.1; length to vent, 11.6; length of head, 5.6; diameter of eye, 1.6; greatest depth, 4.0 millimeters. Dorsal X, 12; anal II, 7; ventrals large, inserted close together. Myomeres, about 15 to vent plus 21 behind. Body rather stout; head large; lower jaw slightly included; premaxillaries not protractile.

Pigmentation.—Chromatophores are thickly distributed over head with a black band extending from tip of snout through eye to back of head. On dorsal aspect they are arranged in about 10 blocks crossing ridge and extending down the sides somewhat. The chromatophores in these blocks are arranged around outlines of scales. On lateral aspect occur about 13 crossbars, narrower than the dorsal blocks, neither opposite nor connecting with them. The last bar is darker than the others, situated at base of caudal, and it has a dark round spot above and below on dorsal

Figure 109.—Young *Boleosoma nigrum nigrum*, stained and cleared

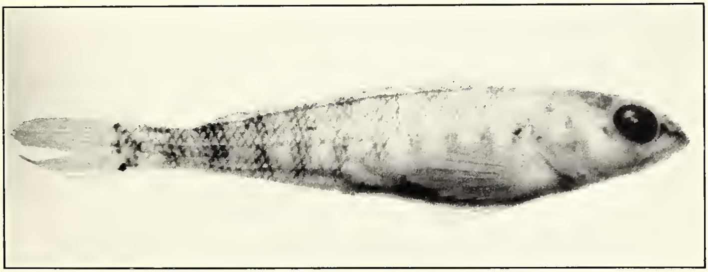

Figure 110.—*Poecilichthys coeruleus coeruleus*, 22.6 millimeters

Figure 111.—*Poecilichthys coeruleus coeruleus*, 22 millimeters, stained specimen

Figure 112.—*Poecilichthys exilis*, 19.5 millimeters

Figure 113.—*Catonotus flabellaris*, 22.6 millimeters

and ventral extremities of body. Almost no chromatophores appear on ventral aspect. The peritoneum is dark. All fins except ventrals have many chromatophores, those of the dorsal giving a checked appearance. The brilliant indigo-blue, orange, and crimson of the male are not indicated in these young specimens.

46. Poecilichthys exilis (Girard). Iowa darter. [*Boleichthys exilis* Girard Jordan, Evermann, Clark, p. 294.]

RECORD OF CAPTURE

The Iowa darter is restricted in its distribution to certain sheltered bays along the Lake shore and several of the larger tributaries.

DESCRIPTION

This darter is distinguished from the rainbow darter by fewer rays in the soft dorsal, more slender body, and the bars confined to middle of sides.

19.5-millimeter stage.—Total length, 19.5; standard length, 16.25; length to vent, 10.0; length of head, 5.0; diameter of eye, 1.5; greatest depth, 2.75 millimeters. Myomeres, 21 to vent plus 19 behind. Dorsal IX, 11; anal II, 7; ventrals close together; caudal squarish. Lateral line incomplete; snout only moderately decurved.

Pigmentation.—Chromatophores are thickly distributed over both jaws, back of head, in 3 to 5 longitudinal rows on dorsal surface to tip of tail (with slight breaks in 5 places), on opercles and preopercles, in 12 clusters along lateral line from head to caudal, speckling whole body, especially dorsally, in single line from vent to tail, in heavy subsurface patches over stomach region and on all fins.

47. Catonotus flabellaris (Rafinesque). Fan-tailed darter.

RECORD OF CAPTURE

This darter is common in the Lake Erie region but is limited to the streams, frequenting the headwaters and never venturing into the open lake.

DESCRIPTION

The fan-tailed darter is similar to *Poecilichthys*, but differs primarily in its projecting lower jaw and scaleless head.

22.6-millimeter stage.—Total length, 22.6; standard length, 19.5; length to vent, 11.5; length of head, 6.0; diameter of eye, 1.5; greatest depth, 3.75 millimeters. Dorsal VIII, 12 (very low); anal II, 8; caudal large and rounded; ventrals close together. Body slender and compressed; head long; very oblique, lower jaw definitely protruding; premaxillaries not protractile.

Pigmentation.—Chromatophores are sparsely distributed on both jaws and front of head, and more heavily on brain region. A very pronounced longitudinal band extends from tip of snout through eye to back of head. Over the dorsal aspect about 10 darker patches are apparent. Chromatophores occur also on surface and below surface in opercular region, in about 10 patches on lateral line forming short horizontal bars and over all lateral surface, sometimes irregular, or in criss-cross pattern. Ventral aspect is clear to vent, thence chromatophores border anal fin and those of lateral pattern on either side meet behind. All fins except ventrals are pigmented.

BREEDING

The fan-tailed darter spawns during the latter part of June and the first of July. Greeley (1927) found egg masses of this species in several places attached to the underside of flat stones in shallow water of moderate to swift current. There were about 400 eggs in a round mass, each one measuring individually about three-thirty-seconds inch in diameter. The young were one-fourth inch at hatching, with rather small yolk sac, and dark spots on the body. A male, probably the parent, was always found under the stone. The water temperature varied from 66° to 76° F.

Family CENTRARCHIDÆ, Sunfishes

48. Micropterus dolomieu Lacépède. Smallmouth bass, black bass.

RECORD OF CAPTURE

Six larvæ, 9.5 to 10 millimeters long, were taken on July 11 in a Helgoland trawl at 6 meters depth near Dunkirk, and others in a young-fish stage at the mouth of Eighteen Mile Creek on July 18, 1928. None was captured in 1929. Larvæ and postlarvæ were obtained for comparison and study from the Caledonia hatchery.

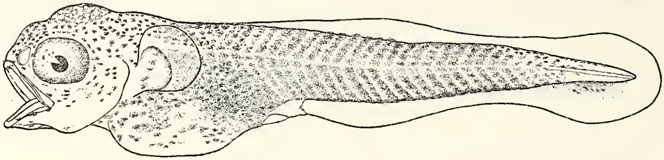

FIGURE 114.—*Micropterus dolomieu*, 8.8 millimeters. (Drawn from hatchery specimen)

The smallmouth bass is very abundant along the shores of Lake Erie, spawning in shallow places in spring and through the first week of July.

DESCRIPTION

This heavily pigmented, robust little fish with its bulbous head and large mouth, extending to the middle of pupil, will not be confused with other forms taken.

Eggs.—Unfertilized eggs taken from the ovary of a 30-centimeter fish on June 29 measured 1.2 to 2.52 millimeters in diameter, mostly 2.2. They were round, semi-transparent, light amber in color, with from six to many comparatively large, clear, dark amber oil globules (largest 0.9 millimeter). The eggs were not adherent, and only loosely joined together.

8.8-millimeter stage.—Total length, 8.8; length to vent, 4.0; greatest depth, 1.8; diameter of eye, 0.85 millimeters. Myomeres, 10 before vent plus 19 behind (very incomplete). Embryonic marginal fin fold originating over end of yolk region, rising to slight elevation at position of later soft dorsal, similar on ventral side; caudal lophocercal; pectorals rounded. Head and yolk region robust, body compressed behind vent; eye large; mouth large, oblique, with maxillary extending to middle of pupil; intestine ending at edge of marginal fin.

Pigmentation.—The whole larva is darkly spotted. Many large stellate chromatophores are massed over bulbous head, with fewer on sides of head and around jaws.

The yolk region is well covered, except on ventral aspect. The myomeres have lines of large, very spreading chromatophores (about 2 wide on each myomere before vent, 1 wide behind), giving an almost even appearance of brown color in the preserved specimens. Chromatophores extend on to base of pectorals, and slightly into caudal. Otherwise, the fins are colorless. The eye is dark.

9.5-millimeter stage.—Total length, 9.5; standard length, 8.5; length to vent, 5.1; greatest depth, 2.1; diameter of eye, 1.0 millimeters. Myomeres about 11 to vent

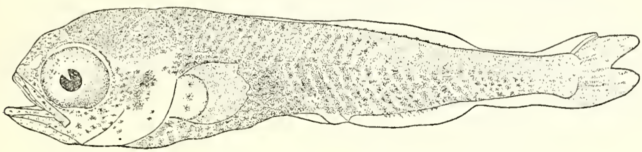

FIGURE 115.—*Micropterus dolomieu*, 9.5 millimeters. (Drawn from hatchery specimen)

plus 22 behind (incomplete). In this stage the head is the deepest part of the fish, rest of body tapering gradually to caudal; stomach much flatter than following stage, intestine probably little coiled. Very slight elements of 13 dorsal and 11 anal rays evident. Greater development of caudal than in following stage probably indicates an older specimen, although of shorter length.

10.0-millimeter stage.—Total length, 10.0; length to vent, 5.25; greatest depth, 2.17; diameter of eye, 1.0 millimeter. Myomeres, 10 before vent plus 19–20 behind (incomplete). Proportions and general appearance as hatchery stock, but differing mostly in light color, resulting from contracted chromatophores which in other

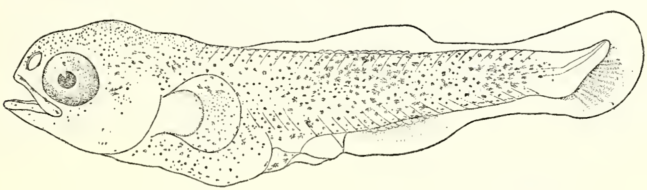

FIGURE 116.—*Micropterus dolomieu*, 10 millimeters. (Drawn from Lake Erie specimen)

specimens were much expanded (contraction constant for lake specimens); however, number and arrangement of chromatophores identical in the two stocks. Apparently, also, the larva in its natural environment develops fin-rays and other adult characters at a slightly greater length than that at which a hatchery specimen—with its normal growth retarded by captivity—will show them, evident from this and the following figure. (See p. 346 for discussion of the effects of artificial rearing on another species.)

9.5-millimeter stage.—Total length, 9.5; standard length, 8.75; length to vent, 5.0; length of head, 2.6; greatest depth, 2.6; diameter of eye, 1.0 millimeter. Stomach region now deeper than head due to large convolutions of intestine; vent still at distance from body. Embryonic marginal fin fold widened above dorsal and anal locations, and fin ray elements much larger than in Figure 116 but in the same numbers. Profile of head higher and more sloping.

19.0-millimeter stage.—Dorsal X, 14; anal III, 12; ventrals and pectorals well developed; caudal forked. Total length, 19.0; standard length, 15.0; length to vent,

9.6; length of head, 5.4; greatest depth, 4.3; diameter of eye, 1.5 millimeters. Mouth very large, oblique, lower jaw projecting, maxillary ending about middle of pupil.

Pigmentation.—Marking is essentially as in younger stages, the sides of body being closely covered with stellate and round chromatophores of varying sizes. Three longitudinal rows occur on either side of dorsal ridge, and a single line on

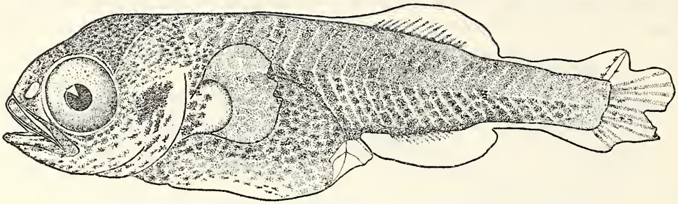

FIGURE 117.—*Micropterus dolomieu,* 9.5 millimeters. (Drawn from hatchery specimen)

either side of ventral ridge behind vent. The peritoneum is black. The head is less pigmented than body, and underside of stomach is much lighter than the rest of body. The fins are colorless.

BREEDING

The black bass spawns from May until early July, incubation taking from 5 to 15 days depending upon the water temperature. Shallow nests are scooped out in the sand for the eggs, and the parent fish guard them carefully until hatched. Reighard (1906) has described in detail the breeding and development of this species.

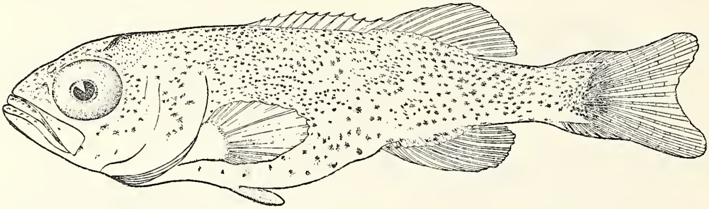

FIGURE 118.—*Micropterus dolomieu,* 19 millimeters. (Drawn from Lake Erie specimen)

49. Aplites salmoides (Lacépède). Largemouth bass. [*Huro floridana* (LeSueur). Jordan, Evermann, Clark, p. 297.]

RECORD OF CAPTURE

The largemouth bass is not as common as its smallmouth relative but is restricted to weedy places along the lake shore, some of the quieter tributaries, and ponds near by. Forty-five young fish, each measuring about 7 centimeters in length, were taken in a seine haul at Long Point Bay on August 23, 1928.

DESCRIPTION

The upper jaw extending to hind margin of eye, and a prominent dark lateral streak serves to distinguish this species from *Micropterus* in which the mouth extends only to middle of pupil and the sides have many short vertical bars.

Figure 119.—*Aplites salmoides*, 75 millimeters

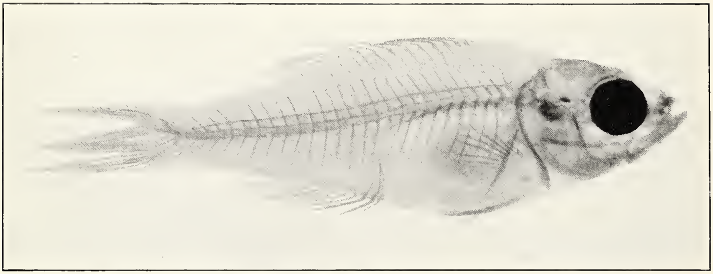

Figure 121.—Young *Eupomotis gibbosus*, stained and cleared

75.0-millimeter stage.—Total length, 75.0; standard length, 70.0; length of head, 28.0; greatest depth, 19.5; diameter of eye, 4.8 millimeters. Body elongate; mouth very large, oblique, maxilla to back of eye; lower jaw projecting; deep notch between dorsals. Dorsal X, 13; anal III, 11.

Pigmentation.—The 75-millimeter fish is slightly greenish above and silvery below. A broad, very dark lateral band extends in mid-line of body from behind head to caudal. Three oblique stripes are apparent across cheek and opercles behind eye. Very small black chromatophores are abundant on top and sides of body, darker and more numerous above lateral band, and arranged more heavily on outline of scales. The belly is white. All fins except ventrals are sprinkled with chromatophores.

BREEDING

The largemouth bass spawns during the period from early April to July. The nesting habits are similar to those of *Micropterus*, and the adhesive eggs are attached to stones. Incubation takes from one to two weeks, depending upon temperature, and the larvæ remain in the nest after hatching for upward of two weeks. At that age they are about 15 to 19 millimeters long.

50. Eupomotis gibbosus (Linnaeus). Common sunfish; pumpkinseed.

RECORD OF CAPTURE

The sunfish is found always in weedy places, whether it be along the lake shore or in the streams and ponds adjoining. It is one of the commoner species of the region.

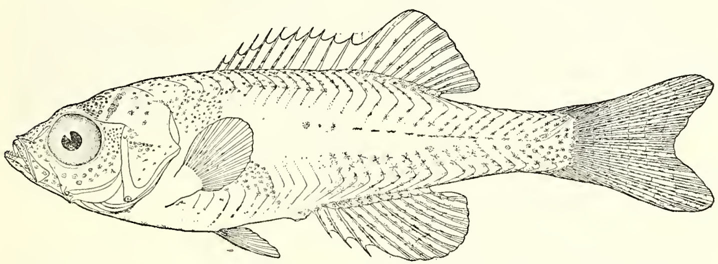

FIGURE 120.—*Eupomotis gibbosus*, 18.5 millimeters

DESCRIPTION

The chubby shape easily identifies these young fishes as sunfish, and the small mouth, scarcely produced operculum, caudal vertebræ numbering 18, and anal spines only 3, distinguish the common sunfish or pumpkinseed from others.

Egg.—The eggs are about 1 millimeter in diameter, demersal, adhering to vegetation or rocks on the bottom.

18.5-millimeter stage.—Total length, 18.5; standard length, 14.5; length to vent, 7.6; length of head, 4.52; snout, 1.1; diameter of eye, 1.5; greatest depth before vent, 4.4; depth behind vent, 3.7; length to dorsal, 5.8; to anal, 8.0 millimeters. Myomeres, 10 to vent plus 18 behind. Dorsal X, 12; anal III, 10. Body ovate, very compressed;

snout short and depressed over eye, interorbital space flat; mouth small, oblique, with maxilla just reaching forward margin of eye.

Pigmentation.—The body is evenly covered with small black chromatophores which follow margins of myomeres. The marking is heavier around jaws, top of head, and cheeks. Single linear spots occur along lateral line from above origin of anal to caudal, and around bases of dorsal and anal. Only the belly is colorless. All fins have chromatophores, fewer on ventrals and pectorals.

BREEDING

The common sunfish is a nest builder, using its fins to hollow out a depression in the mud or sand. The male carefully guards the nest and fearlessly drives off intruders. During the breeding season his colors become much more brilliant, and the ear flaps are conspicuous.

51. Ambloplites rupestris (Rafinesque). Rock bass; goggle-eyed bass.

RECORD OF CAPTURE

The rock bass is found very generally about weedy places on the lake shore and in most of its tributaries. Many young were taken by seines in the Niagara River and alongshore, but none was taken in the surface towings farther out in the lake.

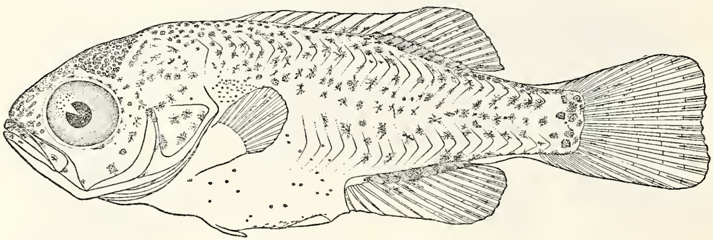

FIGURE 122.—*Ambloplites rupestris*, 10.5 millimeters

DESCRIPTION

The robust, compressed shape of the rock bass resembles other sunfishes, but the large mouth, 5 or 6 anal spines, and 10 to 12 dorsal and anal soft rays distinguish it immediately from others.

10.5-millimeter stage.—Total length, 10.5; standard length 8.9; length, to vent, 5.0; length of head, 3.1; snout, 0.35; diameter of eye, 1.1; greatest depth before vent, 3.18; depth behind vent, 2.3 millimeters. Myomeres, 13 to vent plus 18 behind (only 14 well developed). Body oblong, much compressed; caudal peduncle stout; eye large; large mouth terminal, oblique, maxilla past vertical from anterior margin of pupil; lower jaw barely projecting.

Pigmentation.—The fish is covered by large stellate black chromatophores, especially on tip of both jaws, massed over snout and top of head, and in heavy dorsal and ventral series along margins of body and around fins. The chromatophores are more openly arranged on dorsal half and posterior half behind the vent. The

belly is lighter, with small round chromatophores more sparingly distributed, most numerous along ventral margin. Chromatophores are few on dorsal, caudal, anal, and pectorals, usually situated near their bases. Small subsurface spots are massed over dorsal aspect of air bladder.

BREEDING

Like the common sunfish, the rock bass is a nest builder, scooping out a shallow nest to contain the eggs, over which the male watches with the greatest of patience and care, encouraging the circulation of water over the eggs by fanning with the fins. The breeding season is in May and June.

Family ATHERINIDÆ, Silversides

52. Labidesthes sicculus (Cope). Brook silverside; skipjack.

RECORD OF CAPTURE

The only young specimens were taken along the lake shore in shallow water, at the mouths of Eighteen Mile and Silver Creeks, and in Long Point Bay. It is not of common occurrence in the region.

DESCRIPTION

The very slender body of the silverside, with the shining lateral band from which its name is derived, the short, depressed beak, and two dorsals are characters which readily distinguish the species from any other encountered.

27.0-millimeter stage.—Total length, 27.0; standard length, 23.2; length to vent, 11.4; length of head, 5.6; diameter of eye, 1.8; greatest depth, 3.1 millimeters. Myomeres, 16–17 to vent plus about 25 behind. Dorsal IV–I, 11; anal I, 23; ventrals small, abdominal; pectorals inserted high; caudal forked. Mouth very elongate, terminal and very oblique, with lower jaw slightly projecting; jaws prolonged into a short pointed beak, flattened above and rounded on underside; snout about equal to diameter of eye.

Pigmentation.—The species is characterized by a silvery lateral band from behind head to caudal, edged above in lead color. The cheeks are silvery, and the top of head is rather greenish-yellow at this stage. Chromatophores are distributed on both jaws and on top of head, in interorbital region below the surface and in a heavy main series down dorsal aspect with irregular series on either side to end of second dorsal. They are massed on lateral band, although the individual pigment spots are very small. A double ventral series extends from vent backward. The belly is white. All fins but ventrals are pigmented.

Family SCIAENIDÆ, Drumfishes

53. Aplodinotus grunniens Rafinesque. Sheepshead; freshwater drum; gray bass.

RECORD OF CAPTURE

One young fish, 13.3 millimeters long, was taken on the bottom in 17 meters of water on August 16, 1928, near Port Maitland, Ontario. Adults are common in the lake.

DESCRIPTION

The complete vertical fins at this stage make identification easy. The back is much less elevated but otherwise most of the characters of the adult are evident.

13.3-millimeter stage.—Dorsal VIII–I, 30; anal II, 7; pectorals well developed; ventrals closely behind pectorals; caudal doubly truncate. Total length, 13.3; standard length, 11.0; length to vent, 7.0; length of head, 3.5; diameter of eye, 0.8 millimeter. Myomeres, 12 to vent plus 12 behind. Body rather deep before vent and somewhat compressed; back much less elevated than adult; mouth low, lower jaw included; maxillary to posterior margin of pupil; eye small, placed high; snout wider than eye; teeth in villiform bands, outer enlarged above; preopercle somewhat serrate.

Pigmentation.—Chromatophores are rather large and sparsely distributed over top of head, around jaws, outlining preopercle and at base of pectorals. A subsurface group occurs over the large air bladder and in the jugular region. None is apparent on dorsal or lateral aspects. Ventrally there are about 5 very large, delicate,

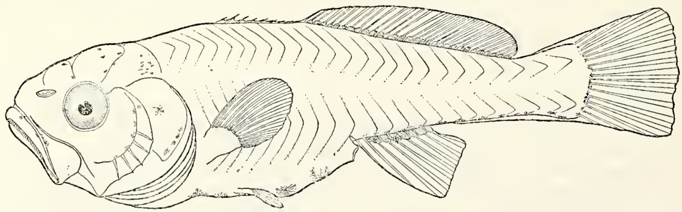

FIGURE 124.—*Aplodinotus grunniens*, 13.3 millimeters

stellate chromatophores from beginning of stomach region to vent. Behind vent about 5 subsurface ones join a double series of about 5 on the surface around base of anal, and the group is continued behind as a single series of 6 to 8 on ventral ridge. The base of caudal is outlined with chromatophores situated on the fin itself.

15.6-millimeter stage.—Total length, 15.6; standard length, 12.5; length to vent, 8.0; length of head, 4.2; diameter of eye, 1.2; greatest depth, 4.0 millimeters. Myomeres, 12 to vent plus 13 behind. Dorsal VIII–I, 30; anal II, 7. The present specimen is slightly older than preceding, but differs only in the increased number of chromatophores. Here, too, the first dorsal has one less spine than given in the description of the adult, but it may be incomplete at this young stage.

Pigmentation.—The pigmentation is very scanty as in the preceding stage, but a few additional chromatophores have appeared at base of dorsal, and in a group on lateral aspect posterior to origin of dorsal, followed by about 20 chromatophores in an irregular broken series. Below the surface others occur on sides and under head, and they are sparingly distributed on all fins.

BREEDING

It is probable that the sheepshead spawns in early summer in Lake Erie.

Figure 123.—*Labidesthes sicculus*, 27 millimeters

Family COTTIDÆ, Sculpins

54. Triglopsis thompsoni Girard. Deep-water sculpin; cockatush.

RECORD OF CAPTURE

Young specimens of this interesting cottid were taken in 1928 from the end of July until the middle of August in the deeper regions, the first time the species has ever been recorded in Lake Erie although adults had been found previously in all of the other Great Lakes (M. P. Fish, 1929 (1)). During 1929 none was taken. The species is interesting in that it is a relic of a former marine arctic fauna, a close relative of the present circumpolar genus *Oncocottus*, and degraded through fresh-water life from a species stranded here in glacial times.

DESCRIPTION

The slender body, elongate cavernous head, gill-membranes free from the isthmus, widely separated dorsal fins, and series of bony processes along either side of dorsal aspect and along ventral ridge behind the anus, and in larger specimens on

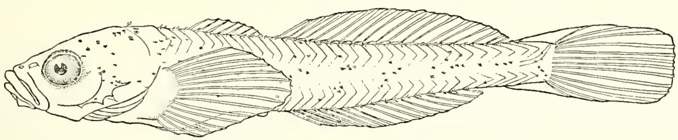

FIGURE 125.—*Triglopsis thompsoni*, 12.5 millimeters

dorso-lateral aspect halfway to lateral line from above vent to a point more than halfway to caudal, distinguish these specimens from all other sculpins taken.

12.5-millimeter stage.—Total length, 12.5; standard length, 10.25; length to vent, 5.0; length of head, 3.25; length of pectoral, 3.0; greatest depth, 1.8; diameter of eye, 0.6 millimeter. Myomeres, 10 to vent plus 23 behind. Dorsal VIII, 19; anal 15; pectorals 15; ventrals I, 4 on one side (in other specimens both sides I, 3), inserted directly below pectorals; caudal exceedingly long. Body very elongate and slender; elongate head, rather cavernous, with elliptical eyes smaller and interorbital space wider than in adult specimens (adult eye 4 in head, much wider than interorbital space and nearly as long as snout, while in these young it is 5.4 in head, slightly less than interorbital space and nearly as long as snout); low dorsal profile gently rising from terminal mouth to back of head, depressed between eyes; snout long and pointed in profile, rather spatulate from above. Rather long, slender, little curved preopercular spine, directed backward and upward, with 3 smaller spines below, the second directed backward, and the others downward; otherwise head unarmed. Body armature consisting of a double series of long, very sharp bony spines directed backward on either side of dorsal aspect from behind head to end of myomeres, and a similar ventral series from behind vent to end of anal fin (about 34 dorsal and 18 ventral). Gill membranes almost free from isthmus, forming only a broad fold across it; branchiostegals 6; dorsals rather widely separated; lateral line conspicuous.

Pigmentation.—A few small round chromatophores occur on top of head, smaller stellate ones between the eyes, and a few on sides of head and around base of pectorals.

A few are evident also on dorsal aspect of stomach region, very large and stellate in shape. Small round ones are arranged in 6 to 7 bands on sides of body extending obliquely from mid-dorsal line forward to a point midway between lateral and mid-ventral lines. These bands are not heavily marked but are made up of 6 to 12 small chromatophores. A few appear on lateral line near base of caudal. On mid-ventral line, there are about 6 widely separated ones to vent, and in more transparent specimens 9 subsurface chromatophores occur from vent to caudal in a single series just above the mid-ventral line.

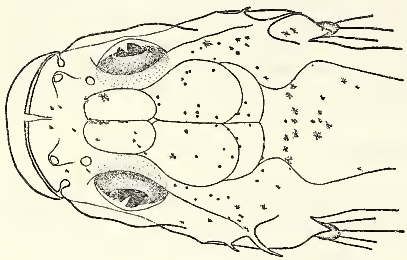

FIGURE 126.—*Triglopsis thompsoni*, 12.5 millimeters. Dorsal view of head

Figure 126 shows the dorsal aspect at this stage with interorbital space much wider than most fresh-water cottids, long spatulate snout, pointed in profile, tubular anterior nares; and long preopercular spine directed obliquely upward. The depressed cavernous nature of the head is not brought out in the drawing.

16.2-millimeter stage.—Dorsal VIII, 18; anal 15, pectorals 15; ventrals I, 4; caudal very long, rounded posteriorly. Total length, 16.2; standard length, 13.0; length to vent, 6.5; length of head, 4.2; length of snout, 1.0; diameter of eye, 0.8; greatest depth, 2.65; interorbital width, 0.9 millimeter. Myomeres, 10 to vent plus 23 behind. Changed from earlier stage principally in deepening of region behind head; heavier pigmentation; the partial covering by skin of preopercular spines, and addition of another series of spiny processes between the dorsal series and the lateral line extending from over vent to a point more than halfway to caudal.

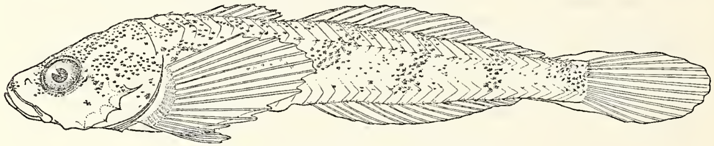

FIGURE 127.—*Triglopsis thompsoni*, 16.2 millimeters

Pigmentation.—The marking is intensified. A few chromatophores occur on upper jaw and many over top and sides of head. They are more or less concentrated over the back and extend downward to lateral line region from behind head to vent. Four broad, well-marked oblique bands behind vent, the last at base of caudal, originate on dorsal aspect and extend obliquely forward nearly to ventral aspect. The ventral aspect and all fins are colorless. The eye is very black.

There are certain characters which differ from the adult descriptions of *Triglopsis thompsoni*, but this species varies widely and our specimens are so small that it seems wisest to identify them thus, considering that these differences may be due to their immature condition.

55. Cottus bairdii kumlieni (Hoy). Lake sculpin, miller's thumb. [*Cottus franklini* Agassiz. Jordan, Evermann, Clark, p. 385.]

RECORD OF CAPTURE

The subspecies *kumlieni* is found in both shallow and deep waters of Lake Erie and the Niagara River. Although only one specimen was captured in 1928 (on June 11 over Seneca Shoal in a bottom Helgoland trawl at 10.5 meters), larvæ and postlarvæ were taken quite generally from June 7 to July 11, 1929, especially along the

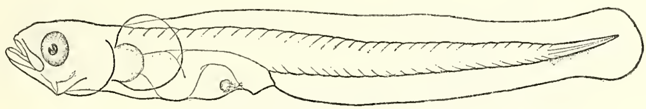

FIGURE 128.—*Cottus bairdii kumlieni*, 6.6 millimeters

Canadian shore from Long Point toward the far western portion of the lake. The subspecies found toward the headwaters of the tributary streams was *C. bairdii bairdii.*

DESCRIPTION

In the youngest stages it is quickly recognized by the single large chromatophore at vent, myomere count of 10 plus 23, and the maxillary reaching only to front of pupil, and later by its stouter body and lack of the even series of spines on the body characteristic of *Triglopsis.* The marginal fin-ray counts of all of our specimens range slightly higher than the usual number given in descriptions of adults, being consistently dorsal VI to VIII, 16 to 17; anal 12 to 15, but the variability of the sculpins is great and the increased number may be constant for this subspecies.

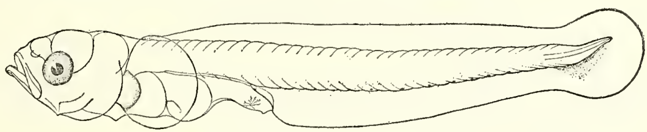

FIGURE 129.—*Cottus bairdii kumlieni*, 7.2 millimeters

6.6-millimeter stage.—Total length, 6.6; length to vent, 2.6; length of head, 1.15; snout, 0.3; diameter of eye, 0.31; greatest depth before vent, 0.9; depth behind vent, 1.1 millimeters. Myomeres, 10 to vent plus 23 behind. Distinguished by very long marginal fin-fold originating at nape, short intestine, very large unrayed pectorals reaching halfway to vent, very broad head with dorsal profile rounded above; lophocercal tail. Although the intestine already is coiled once, some yolk material remains, containing one moderate oil globule near vent.

Pigmentation.—The body is almost colorless except for a single very large, stellate chromatophore on underside shortly before vent, and 4 very small, hardly perceptible, linear-shaped ones on ventral margin of tail.

7.2-millimeter stage.—Total length, 7.2; length to vent, 3.1; length of head, 1.3; snout, 0.35; diameter of eye, 0.35; greatest depth before vent, 1.03; depth behind vent, 1.2 millimeters. Myomeres, 10 to vent plus 24 behind. Much like preceding

but whole body heavier. Stomach region deeper, intestine more convoluted, all trace of yolk material gone. Marginal fin fold as in preceding stage, but notochord turned slightly upward and concentration marking beginning of caudal ray development evident below.

Pigmentation.—Black eyes, a large single vent spot, and six tiny chromatophores along ventral ridge of tail characterize this larval stage.

10.0-millimeter stage.—Total length, 10.0; length to vent, 4.5; greatest depth, 1.5; diameter of eye, 0.5 millimeter. Myomeres, 11 to vent plus 23 behind. Dorsal

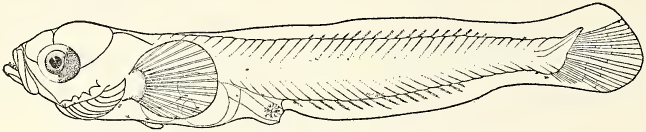

FIGURE 130.—*Cottus bairdii kumlieni,* 10 millimeters

marginal fin fold originating just behind head, rising evenly and slowly to the highest point about halfway between vent and peduncle; anal similar to dorsal; starting behind vent, 16 elements of dorsal fin rays, widely separated, and 13 anal below; ventrals I, 4, inserted just behind pectorals; pectorals 14, fully rayed, large, round; caudal rayed. Head and body stout to anus, compressed behind; interorbital space wider than in adult; eye rather small and bulging; mouth terminal, oblique, lower jaw projecting; preopercle with a short, straightish spine directed backward and upward, and two smaller spines below; subopercle with a stout spine directed downward.

Pigmentation.—Four surface chromatophores occur on ventral aspect at beginning of stomach region, 1 (subsurface) at base of left pectoral, 1 of very large size on

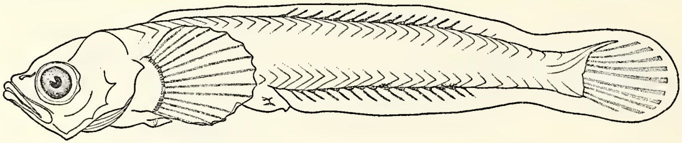

FIGURE 131.—*Cottus bairdii kumlieni,* later 10 millimeters

left side of intestine almost at vent, and 1 on ventral aspect slightly less than halfway from vent to end of body.

Later 10.0-millimeter stage.—Total length, 10.0; standard length, 9.0; length to vent, 4.16; length of head, 2.12; snout, 0.55; diameter of eye, 0.45; greatest depth before vent, 1.7; depth behind vent, 1.6 millimeters. Myomeres, 10 to vent plus 24 behind. Slightly older specimen of same length as preceding but with head further developed, and elements of dorsal and anal fins quite completely formed. Pectorals longer, reaching three-quarters of distance from base to vent.

Pigmentation.—Unchanged from preceding.

11.0-millimeter stage.—Total length, 11.0; standard length, 9.5; length to vent, 4.45; length of head, 2.6; snout, 0.75; diameter of eye, 0.6; greatest depth before vent, 2.1; depth behind vent, 1.3 millimeters. Myomeres, 12 to vent plus 22 behind.

Dorsal VII, 17; anal 14; pectorals reaching practically to vent; caudal well formed; ventrals I, 4. Resembling later stages in general characters, but body slightly more slender, fins lower, and heavy adult pigment lacking.

Pigmentation.—Chromatophores are limited to 2 on either side of head above eye, 1 at ventral extremity of each pectoral base, and 1 which forms the characteristic vent spot of earlier stages.

19.0-millimeter stage.—Total length, 19.0; standard length, 15.1; length to vent, 8.25; length of head, 5.0; diameter of eye, 1.75; greatest depth, 3.5 millimeters. Myomeres, about 12 to vent plus 23 behind. Dorsal VIII, 16; anal 12; ventrals I, 4. Body rather robust but more slender than *C. bairdii bairdii;* head very broad; preopercle with short, sharp, straightish spine turned upward and backward, with two smaller spines below; bones of head not cavernous; mouth terminal, oblique, maxilla to pupil; gill membranes attached to wide isthmus.

Pigmentation.—Small brownish chromatophores evenly cover dorso-lateral aspect of head and body and occur on and below the surface in brain region. Two wide bands obliquely cross dorsal ridge beginning at dorsal; another wider band extends down either side beyond the lateral line; and a fourth long bar appears at end of dorsal, followed by two or three small bars on caudal peduncle. Below the lateral line, pigmentation is in blotches with clear spaces between where skin is very white.

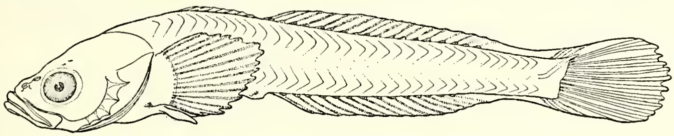

FIGURE 132.—*Cottus bairdii kumlieni,* 11 millimeters

Ventrally about 15 very small chromatophores occur in gill region, a series of about 9 on either side of anal, and a small group behind this fin. All fins but ventrals are spotted or barred with chromatophores.

56. Cottus bairdii bairdii Girard. Sculpin, miller's thumb. [*Cottus ictalops* (Rafinesque). Jordan, Evermann, Clark, p. 385.]

RECORD OF CAPTURE

A single larva 6 millimeters long taken in the far northwestern portion of the lake on July 2, 1929, differs from specimens of *C. bairdii kumlieni* found to the eastward. Its capture immediately off the Detroit River suggests the subspecies *C. bairdii bairdii,* which is common in the tributaries and which might under certain circumstances be carried into the lake itself. Sculpins vary so considerably that this may be identical with *kumlieni,* but the differences are sufficient to warrant a tentative separation.

DESCRIPTION

The present larva resembles *C. bairdii kumlieni* in myomere count (10 plus 22 or 23), but differs in its very large mouth, maxilla reaching to middle of eye whereas in the latter it reaches barely to front of pupil, a wider interorbital space, and a more conspicuous chromatophore series on ventral aspect of tail.

6.0-millimeter stage.—Total length, 6.0; standard length, 5.6; length to vent, 2.5; length of head, 1.2; diameter of eye, 0.35; greatest depth before vent, 0.9; depth behind vent, 0.35 millimeter. Myomeres, 10 to vent plus 22 (23) behind. Embryonic marginal fin fold originating over fifth myomere behind head (in *kumlieni* over first), with considerable concentration indicating formation of caudal rays in the still lophocercal tail (much more development than in *kumlieni* of 7.2 millimeters); large unrayed pectorals reaching halfway to vent; very broad head with longer and more pointed snout than in *kumlieni*.

Pigmentation.—Several chromatophores occur on ventral surface shortly before vent (but not as large nor stellate as in *kumleini*), and a conspicuous series of rather

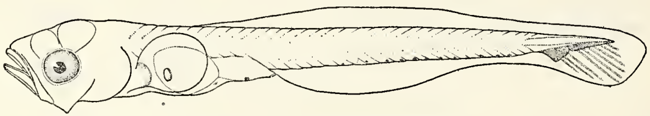

FIGURE 133.—*Cottus bairdii bairdii*, 6 millimeters

large rounded spots is evident along ventral surface of tail to caudal (very few, if any, small chromatophores in *kumlieni* of like size). The body is otherwise colorless.

57. Cottus cognatus Richardson. Muddler; miller's thumb; northern sculpin.

RECORD OF CAPTURE

During August, 1928, from the New York State line around the eastern end of the lake to Tecumseh Shoals on the Canadian side, specimens of this northern stream species were taken in small numbers but rather generally in Petersen and Helgoland

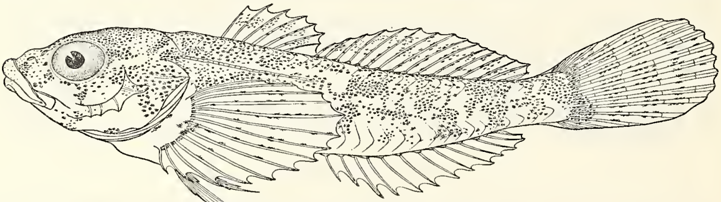

FIGURE 134.—*Cottus cognatus*, 18 millimeters

trawls from 16 to 23 meters. *C. cognatus* had not been recorded previously in Lake Erie.

DESCRIPTION

The young of this species closely resemble *C. bairdii kumlieni* in their rather short bodies, with gill membranes attached to the isthmus, but differ in having pelvic fin ray count I, 3.

18.0-millimeter stage.—Total length, 18.0; standard length, 14.0; length to vent, 8.0; length of head, 5.0; snout, 1.2; diameter of eye, 1.33; greatest depth before vent, 3.3; depth behind vent, 2.4; length to dorsal, 5.6; to anal, 8.5 millimeters. Myomeres, 10 to vent plus 19 behind. Dorsal VII, 17; anal 12. Body short and stout; snout not

very obtuse; maxillary to pupil; eye almost 4 in head; eyes rather close together; preopercular spine very long, hooklike, pointed upward and backward; dorsals contiguous; anal inserted under fourth ray of soft dorsal; lateral line incomplete; vent nearer caudal than tip of snout.

Pigmentation.—The whitish body is marbled with black chromatophores in a pattern similar to *Cottus baridii kumlieni* of like size, though more broken up.

21.5-millimeter stage.—Total length, 21.5; standard length, 17.8; length to vent, 9.2; length of head, 5.3; greatest depth, 4.3; diameter of eye, 2.0 millimeters. Myomeres, 10 to vent plus 19 behind (incomplete). Dorsal VIII, 17; anal 11; ventrals I, 3; pectorals not quite to vent.

Pigmentation.—The body is mottled with black as in the preceding stage. The definite greenish and reddish colors of adult specimens are not evident in these younger stages, except for a slight greenish tinge over the head.

58. Cottus ricei (Nelson). Rice sculpin.

RECORD OF CAPTURE

This species was taken on August 25, 1928, in a Helgoland trawl at 22 meters below the surface on Tecumseh Shoals, the first record of its occurrence in Lake Erie

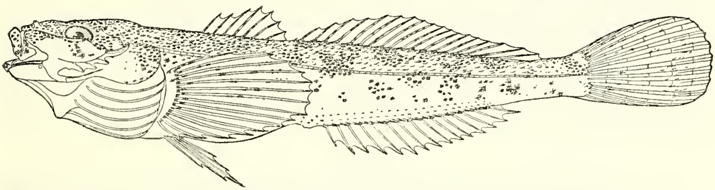

FIGURE 135.—*Cottus ricei*, 27.5 millimeters

(M. P. Fish, 1929). Other larger specimens were obtained by C. W. Greene from the stomach of a ling, which also was captured near Dunkirk in the same year.

DESCRIPTION

This one small sculpin differed from all others in its very long preopercular spine hooked backward and upward, complete lateral line, with numerous small prickles covering the body above, extending over top of head and between eyes, and with similar ones on ventro-lateral aspect of the tail.

27.5-millimeter stage.—Total length, 27.5; standard length, 23.0; length to vent, 12.0; snout, 2.0; length of head, 6.0; breadth of head, 6.4; greatest depth, 4.1; interorbital width, 1.4; diameter of eye, 1.5 millimeters. Dorsal VII, 18; anal 15; ventrals I, 4; pectorals 15, reaching to anal origin. Head very much depressed, broad and flat so that its breadth is greater than its length; outline rather tadpolelike; eyes closer together than in *Triglopsis* specimens; preopercular spine very long, hooked backward and upward, with a "buffalolike appearance"; other 3 spines hooked downward and the lowest concealed. Above lateral line space covered with stiff prickles, hooked backward, largest on either side of dorsal ridge, extending over top of head and between eyes. Lateral line complete.

Pigmentation.—The marking consists of irregular mottling of brown, especially over head and dorsal aspect, becoming scarcer over sides. Ventral aspect and ventrals are colorless. The other fins are mottled.

Family GASTEROSTEIDÆ, Sticklebacks

59. **Eucalia inconstans** (Kirtland). Brook stickleback.

RECORD OF CAPTURE

The brook stickleback, true to its name, was found in the many creeks tributary to Lake Erie and weed beds of the Niagara River, but never in the lake itself.

DESCRIPTION

The absence of lateral plates, only 5 or 6 dorsal spines, unkeeled tail, and rounded caudal are field characters which brand this stickleback immediately.

19.6-millimeter stage.—Total length, 19.6; standard length, 17.1; length to vent, 9.9; length of head, 5.4; greatest depth, 4.9; diameter of eye, 2.0 millimeters. Myomeres, 11 to vent plus 18 behind. Dorsal IV–I, 10 (spines short, even in length); anal I, 10; caudal rounded. Elongate body, but rather stout; caudal peduncle without a keel; smooth skin without any lateral plates; ventral spines small.

Pigmentation.—Chromatophores occur on both jaws, and thickly over top of head, so that the unpigmented pores are prominent on forepart of head. The chromatophores extend evenly and thickly down dorsal ridge and up over dorsal rays, evenly also on lateral aspect where they outline the myomeres. Some white patches of clear skin appear at intervals but not in a pattern. Ventral surface of head and stomach region is pale.

BREEDING

The brook stickleback is a nest-builder and defends its young with the utmost courage. During the breeding season the males become jet black, tinged everywhere with vivid copper color.

60. **Gasterosteus aculeatus** Linnaeus. Two-spined stickleback.

RECORD OF CAPTURE

A few young of this species were taken in weed beds of the Niagara River. They are of rare occurrence in the region.

DESCRIPTION

The two-spined stickleback is easily recognized by the single pair of large spines forming the first dorsal, implied by its name, the appearance of lateral plates, keeled caudal peduncle, and lunate caudal.

16.5-millimeter stage.—Total length, 16.5; standard length, 14.5; length to vent, 9.7; length of head, 5.0; snout, 1.6; diameter of eye, 1.65; greatest depth, 3.8 millimeters. Myomeres, 15 to vent plus 16+ behind. Dorsal II–I, 11; anal I, 9. Body fusiform; caudal peduncle short but very slender, distinctly keeled; bony plates on sides not yet evident in these young specimens.

Pigmentation.—The body is greenish in tinge but not as deeply colored as older stages. Chromatophores are arranged thickly over top of head and in about 10 short

Figure 136.—*Eucalia inconstans*, 19.6 millimeters

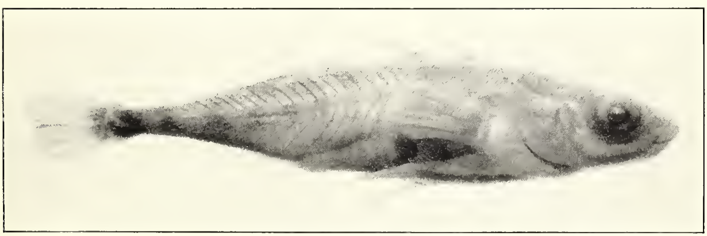

Figure 137.—*Gasterosteus aculeatus*, 16.5 millimeters

patches along dorsal ridge. There are five patches on lateral line which connect more or less with some of the dorsal groups by oblique bars, those of the tail region extending completely to ventral margin of body. Few chromatophores occur on fins except about the two dorsal spines and near the proximal extremity of caudal.

BREEDING

An elaborate nest is made by the two-spined stickleback from bits of grass and twigs on the sandy bottom of a stream. The male watches over the nest with great patience, fanning it with his fins to increase the circulation of water, and leaving only to search for food or drive off invaders. He is brilliant at this time, blue and green above and red below. It is reported that the male often kills his mate after spawning.

Family GADIDÆ, Codfishes

61. Lota maculosa (LeSueur). Ling; eel-pout; lawyer; gudgeon; burbot.

RECORD OF CAPTURE

Larval and postlarval stages, 3 to 15 millimeters, were quite common in meter-net hauls from 5 to 60 meters from the middle of June to the middle of August, 1928,

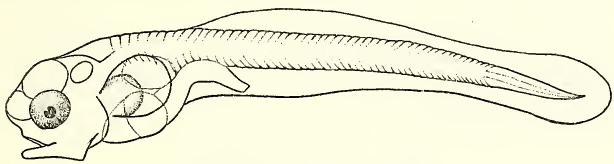

FIGURE 138.—*Lota maculosa*, 3.5 millimeters

especially in the deep hole off Long Point, and from the first week of June until the middle of July, 1929.

DESCRIPTION

The typical rounded gadoid head and very numerous myomeres render the earliest stages readily identifiable, and the elongate marginal fins, chin barbel, and isocercal tail mark the older specimens as essentially different from any other lake species.

3.5-millimeter stage.—Total length, 3.5; standard length, 3.25; length to vent, 1.5; greatest depth, 0.7; diameter of eye, 0.25 millimeters. Myomeres fairly well developed, about 14 to vent plus about 38 behind. Embryonic marginal fin fold originating over the fifth myomere behind head, rising to its highest point just behind vent, tapering gradually to caudal region, and continuing thence forward along ventral side of stomach region, identical with the dorsal. Intestine ending blindly at a distance from the body, but not quite at edge of marginal fin, as in cod, haddock, and pollock. Bulbous forehead making mouth inferior, lower jaw slightly protruding; eye about median in head. Larva characterized chiefly by the very transparent, colorless, slender body with many myomeres, relatively short intestine, lophocercal tail, well-developed rounded pectorals, and pigment confined to the dark eyes.

4.5-millimeter stage.—Total length, 4.5; standard length, 4.35; length to vent, 1.75; greatest depth, 0.95; diameter of eye, 0.4 millimeters. Myomeres, 14 to vent

plus 36 + behind. Forehead starting to recede although still much rounded and projecting no farther than tip of upper jaw.

Pigmentation.—One black chromatophore is evident on each side over posterior part of air bladder.

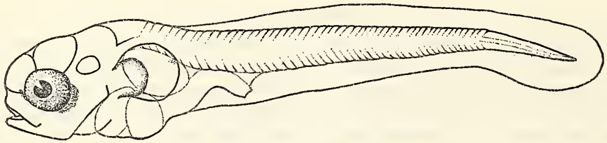

FIGURE 139.—*Lota maculosa*, 4.5 millimeters

6-millimeter stage.—Total length, 6.0; standard length, 5.7; length to vent, 2.5; greatest depth, 1.1; diameter of eye, 0.4 millimeters. Dorsal contour of head more sloping than before, mouth terminal, and lower jaw slightly projecting.

Pigmentation.—The body retains the transparent colorless condition of preceding stages, relieved only by the addition of a double line of five large stellate subsurface chromatophores over dorsal aspect of air bladder (scarcely evident in fig. 140).

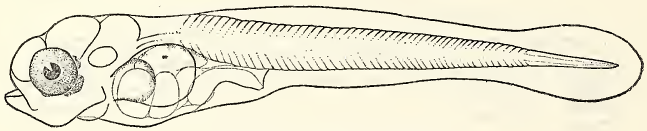

FIGURE 140.—*Lota maculosa*, 6 millimeters

6.8-millimeter stage.—Total length, 6.8; standard length, 6.6; length to vent, 3.0; greatest depth, 1.5; diameter of eye, 0.5 millimeters. Myomeres, 15 to vent plus 40 behind. Following the stage shown in Figure 140, larva apparently grows in depth and breadth more rapidly than in length, for in Figure 141, although the specimen drawn is only eight-tenths of a millimeter longer than in the preceding, the body is

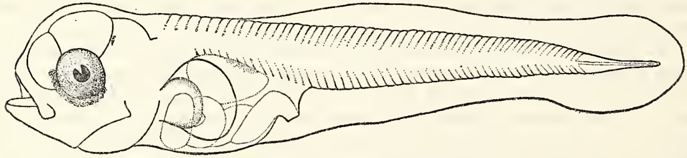

FIGURE 141.—*Lota maculosa*, 6.8 millimeters

much heavier so that the depth is contained 4.53 in total length, as compared with a proportion of 5.4 in the smaller specimen. Fins unchanged.

Pigmentation.—The only color difference consists in the addition of a few more chromatophores over stomach region.

10.9-millimeter stage.—Total length, 10.9; standard length, 9.6; length to vent, 5.0; greatest depth, 2.1; diameter of eye, 0.8 millimeters. Myomeres, 20 to vent plus 32 behind. Second dorsal about 67 rays; anal about 64 rays (incomplete). Many of

the later characters of the adult evident especially in contour of head and mouth; barbel represented by a large fleshy protuberance; intestine open at margin of body; ventrals apparent below pectorals; deep notching of marginal fin fold marking out position of the two dorsals, and most of dorsal, anal, and caudal rays indicated. Body ending in a straight point forming an isocercal tail.

Pigmentation.—Chromatophores are confined to the subsurface patch above stomach region and about 25 rather large roundish black spots distributed over

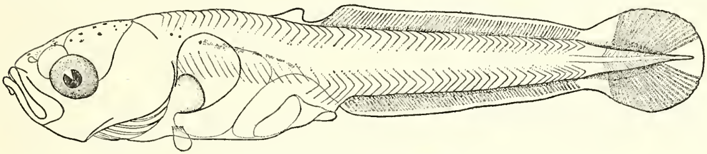

FIGURE 142.—*Lota maculosa*, 10.9 millimeters

top of head, followed by subsurface chromatophores hardly discernible over anterior part of notochord (possibly continuing for its entire length).

14.0-millimeter stage.—Total length, 14.0; standard length, 13.2; length to vent, 7.0; greatest depth, 2.75; diameter of eye, 1.0 millimeters. This stage differs from the adult in slightly shorter upper jaw. Marginal rays entirely formed at this stage, and sections of embryonic fin persist to connect caudal with dorsal and anal fins; ventrals larger and completely rayed.

Pigmentation.—A few stellate chromatophores occur on both jaws, followed by very distinct preorbital, postorbital, and opercular patches which give the impression

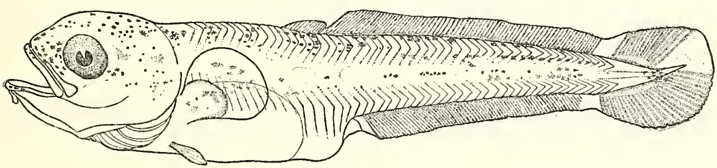

FIGURE 143.—*Lota maculosa*, 14 millimeters

of a lateral pigment band on either side of head. Many large chromatophores are massed over top of head. Lateral line is marked by a single broken series of large chromatophores extending to the extreme caudal region, becoming wider with more numerous and smaller subsurface spots toward the end. Dorsal aspect has numerous pigment spots arranged irregularly in 10 to 12 groups, each one consisting of a double row of large, close-set chromatophores outlining dorsal fins and others more sparsely distributed extending halfway to lateral line. Although the breaks in dorsal and lateral series do not necessarily coincide, a somewhat banded impression is given, emphasized in older specimens.

19.0-millimeter stage.—Total length, 19.0; standard length, 17.0; length to vent, 9.5; greatest depth, 3.15; diameter of eye, 1.2 millimeters. Characters essentially same as in preceding stage, except for completely formed fins and barbel, and intensified pigmentation. The identification of these postlarval and young-fish

stages is rendered easy by the very long marginal fins, and the persistent isocercal tail which no other local species exhibits.

30.5-millimeter stage.—Total length, 30.5; length to vent, 15.5; greatest depth, 5.0; diameter of eye, 1.8 millimeters. Dorsal 11 to 13, 66–67; anal 60–67; ventrals 7. Myomeres, 21 to vent plus 38 behind.

Pigmentation.—Top and sides of head down to posterior margin of eye are thickly pigmented, most heavily in a band through eye from tip of snout to opercle. Only an occasional chromatophore is evident below eye, and a few outline the lower jaw. Dorsal and lateral aspects are patterned with irregular groups of chromatophores, giving a checkered or marbled effect. Ventral side is unmarked except for a double series of about 20 chromatophores along base of anal fin. A few chromatophores occur on all fins except anal.

A young burbot, 178 millimeters in total length, representing probably a 1-year-old fish, was seined at the mouth of Silver Creek on September 4, 1928, by J. R. Greeley, who states in a letter to the author, "I have known of *Lota* about this size

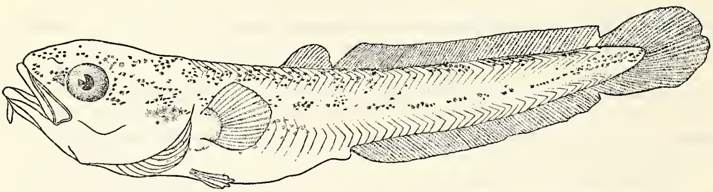

FIGURE 144.—*Lota maculosa*, 19 millimeters

being taken in creeks, and call to mind one collection of several specimens that came from Canandaigua Lake inlet, collected by Doctor Eaton of Hobart College."

BREEDING

Little is known of the breeding habits of the ling, but adults are reported full of spawn from November until March. Our records of early larvæ would indicate that hatching occurs in early summer, up until the last week of June.

62. Species A.

RECORD OF CAPTURE

Eighteen larvæ ranging from 5.3 to 6.8 millimeters long were taken on July 1 and 2, 1929, along the far western shore of Lake Erie in comparatively shallow water.

DESCRIPTION

The present specimens differ considerably from all others taken by the survey. They are characterized by a short intestine as in the cottids and centrarchids, but the compressed head eliminates the former possibility, and the slender elongate body is unlike that of the larval *Micropterus*, the only member of the sunfish family whose young are known. In the absence of further stages, no attempt at identification is made.

5.1-millimeter stage.—Total length, 5.1; standard length, 5.0; length to vent, 2.1; length of head, 0.9; diameter of eye, 0.37; greatest depth before vent, 0.66; depth

behind vent, 0.34 millimeter. Myomeres, 10 to vent plus 18 behind. Characterized by the long slender body, short intestine, very large air bladder, rounded dorsal contour of head, and large, low, oblique mouth.

Pigmentation.—Chromatophores are scattered sparsely over top of head, nape, and on body above pectorals. Others are massed over dorsal aspect of air bladder. A double or irregular single series occurs in jugular region to below front of air bladder. One large stellate spot is apparent on top of intestine immediately before vent, and a double series along ventral aspect of body from vent to caudal. There are four or more linear chromatophores along lateral line behind vent.

6.5-millimeter stage.—Total length, 6.5; standard length, 6.2; length to vent, 2.8; length of head, 1.2; diameter of eye, 0.46; greatest depth before vent, 0.9; depth behind vent, 0.5 millimeter. Myomeres, 10 to vent plus 18 or 19 behind. Generally as before but pigment intensified. Dorsal marginal fin fold originating about seventh myomere behind head; tail lophocercal but beginning of caudal rays evident below.

Pigmentation.—Chromatophores are numerous over top of head, eye, lower jaw, and sides of head. The jugular, lateral, and ventral series have many more chromatophores than in preceding stage. Dorsal chromatophores occur from head to origin of fin fold, and near tip of tail.

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SALMON-TAGGING EXPERIMENTS IN ALASKA, 1930[1]

By Willis H. Rich, Ph. D., *Professor of Zoology, Leland Stanford Junior University*

CONTENTS

INTRODUCTION

Two distinct series of tagging experiments were carried out by the Bureau of Fisheries during the summer of 1930. The first involved the tagging of 1,994 salmon liberated from the traps located in the region of Cape Fox and Sitklan and Kanaganut Islands. This was undertaken at the request of the Department of Fisheries of the Dominion of Canada and was designed to test the extent to which these traps drew upon the salmon runs native to streams in British Columbia. The second series of experiments was conducted near the entrance to Kasaan Bay on the eastern coast of Prince of Wales Island, southeastern Alaska. One thousand four hundred and ninety-five fish were tagged and liberated from traps situated both north and south of the entrance to the bay. These experiments were carried out to test the extent to which these traps drew on the Kasaan Bay runs and to what extent on runs native to streams located elsewhere, the resident purse seiners claiming that the traps caught almost exclusively Kasaan Bay fish while the trap operators claimed that the traps caught chiefly migratory fish that were passing through Clarence Strait on their way to more distant spawning grounds.

The reader is again referred to the preceeding reports of this series,[2] especially that for 1923, for a description of the tags and methods used.

The actual tagging and the collection of most of the data was carried out in an efficient manner by F. W. Hynes, warden, Alaska Service, who tagged approximately 3,500 salmon between July 13 and August 14. The data were, in part, compiled and

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[1] Bulletin No. 11. Approved for publication Mar. 26, 1932.

[2] Second Experiment in Tagging Salmon in the Alaska Peninsula Fisheries Reservation, Summer of 1923, by Charles H. Gilbert and Willis H. Rich. Bulletin, U. S. Bureau of Fisheries, Vol. XLII, 1926, Document No. 991, pp. 27–75. Washington.

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tabulated by Russell R. Vickers, of Stanford University. The list of tags attached follows:

TABLE 1.—*Tags attached in southeastern Alaska during 1930*

Experiment No.	Date	Serial Nos.	Species of fish tagged						Locality
			Red	Pink	Chum	Coho	King	Steelhead	
1	July 13	9001–9250	51	148	27	21			Stitklan Island.
2	do	9251–9500	35	166	6	40	2		Kanaganut Island.
3	July 25	9501–9750	5	240	2	1			Stitklan Island.
4	do	9751–10000	7	232	3	6			Kanaganut Island.
5	July 26	10001–10250		243	7				Cape Fox.
6	July 29	10251–10500	35	146	22	47			South side, entrance to Kasaan Bay.
7	Aug. 3	10501–10647		136	2	9			North side, entrance to Kasaan Bay.[1]
8	do	10648–10742	1	87	1	5		1	Do.[2]
9	do	10743–10997	8	200	18	26		1	Do.
10	Aug. 7	10998–11250		246		6	1		Cape Fox.
11	Aug. 8	11251–11500	6	230	11	3			Kanaganut Island.
12	do	11501–11750	5	238	3	4			Sitklan Island.
13	do	11751–12000	10	135	95	10			South side, entrance to Kasaan Bay.
14	Aug. 14	12001–12250	6	191	45	8			North side, entrance to Kasaan Bay.
15	do	12251–12500	1	234	3	12			Do.[1]
Total		9001–12500	170	2,872	245	198	3	2	

[1] Near the south entrance to Windfall Harbor. [2] Just north of the entrance to Windfall Harbor.

Tags were recovered from a few minor localities which have not been described in the previous papers dealing with salmon-tagging experiments in Alaska. These previously undescribed places are as follows:

Black Island. Southern entrance to Behm Canal.
Bulkley River. A tributary of the Skeena River, British Columbia.
Cape Fox Island. A small island just off Cape Fox.
Captain Cove. Near the northern end of Pitt Island, British Columbia.
Chasina Point. Eastern entrance to Cholmondeley Sound, east coast of Prince of Wales Island.
Cone Island. At the southern entrance to Thorne Arm, Revillagigedo Island.
Foggy Island. Probably an island in Foggy Bay, Revillagigedo Channel.
Hadley. A settlement on Lyman Anchorage, Kasaan Peninsula, Clarence Strait.
Harry Bay. In Nakat Inlet.
Hidden Inlet. Indenting the mainland north of Pearse Island, Portland Inlet.
Island Point. In Kasaan Bay, latitude 55° 22′ 30″.
Kelp Island. Just south of Duke Island, latitude 55° 52′, longitude 131° 16′.
Kitemaat River. Tributary to Douglas Channel, British Columbia.
Lull Point. Southern end of Thatcher Island, Chatham Strait.
Mill Bay. Near the mouth of Nass River, Portland Inlet, British Columbia.
Parkin Island. In Port Simpson just south of Portland Inlet, British Columbia.
Porcher Island. In British Columbia, latitude 54°, longitude 130° 30′, off the mouth of the Skeena River.
Ray Anchorage. East coast of Duke Island.
Ratz Harbor. East coast of Prince of Wales Island, latitude 55° 53′.
Rip Point. Southern entrance to Moira Sound.
Tolstoi Point. Southern entrance to Tolstoi Bay, east coast of Prince of Wales Island, latitude 55° 40′
West Rock. Southwest of Duke Island, Clarence Strait.
Willard Inlet. Indenting mainland, Dixon Entrance, longitude 130° 40′.
Wedge Island. Off east coast Prince of Wales Island, Clarence Strait, latitude 55° 08′.

Table 2.—*Returns from pink salmon tagged near Cape Fox*

[In this and subsequent tables the figures in the columns headed "Time" indicate, in days, the least and the greatest time that elapsed between tagging and reported recapture.]

Locality of recapture	Locality and date of tagging																Total number returned
	Sitklan Island, July 13		Kanaganut Island, July 13		Sitklan Island, July 25		Kanaganut Island, July 25		Cape Fox, July 26		Cape Fox, Aug. 7		Kanaganut Island, Aug. 8		Sitklan Island, Aug. 8		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Dixon Entrance—east of Cape Fox:																	
Cape Fox	2	1–34	2	2–3	2	20–22	5	2–17	2	8–9	16	1–4	15	1–5	7	1–5	51
Cape Fox Island	3	3–5	1	5	1	24	1	10			1	2	1	8	2	6–8	10
Boat Rock											3	2–4	22	1–7	17	1–7	42
Harry Bay															1	4	1
Kanaganut Island			2	11–14	16	3–14	24	1–19	8	0–7	2	3–8	21	0–5	18	1–7	91
Sitklan Island			3	3–12	4	13–30	[1] 1	(?)	4	4–19	2	2	2	1	10	1–6	26
Willard Inlet													1	3	2	3	3
Fillmore Inlet	2	30–32	2	32			2	14–15	2	19–20	5	5–8	6	4–7	15	4–6	34
Hidden Inlet					3	23–26	3	11–12			1	2	2	1			9
Tombstone Bay	2	7–10	2	18–29	10	10–34	9	5–14	1	17							24
Revillagigedo Channel:																	
Tree Point					7	17–29	6	1–16	2	13–22	7	1–5	3	2–8	11	2–8	36
Foggy Point	3	2–5			6	1–2	10	1–9	5	0–4	22	1–3	7	1–4	4	1–10	57
Kirk Point			1	3													1
Kah Shakes	7	1–19	3	1–17	3	13–17	1	1	1	5	3	3					18
Boca de Quadra	5	9–18	4	9–39	7	15–26	4	3–6	8	2–5	1	1	2	0			31
Marten Arm							1	12	1	7	1	4			2	1–3	5
Point Sykes	1	3											1	6	1	8	3
Kelp Island	1	35															1
Duke Island											1	2					1
Ray Anchorage											1	5					1
Point Alava											1	9					1
Lucky Cove	5	3–4	9	2–7													14
Thorne Arm			1	4					2	2			1	4			4
Crab Bay	1	7															1
Carroll Point									1	17	2	5					3
Carroll Island											1	7			1	6	2
Behm Canal—South:																	
Smeaton Bay	6	4–10	5	2–6	3	4–7	5	7–8	[2] 24	2–16			[1] 1	(?)	1	3	45
Rudyerd Bay									1	4							1
Clarence Strait—eastern shore:																	
Club Rocks	1	2															1
Hall Cove											1	4	1	1			2
Annette Island, west shore							1	19					1	3			2
Bronaugh Islands									1	3							1
Gravina Island					1	26	1	5	3	5–21			2	1–3			7
Vallenar Bay			1	34					1	4					2	8	4
Vallenar Point									1	8	1	4					2
Niblack Point									1	4							1
Behm Canal—North:																	
Bond Bay															2	0–3	2
Black Island			3	2–3							3	4–8	3	3–7			9
Loring					1	8											1
Clarence Strait—western shore:																	
Rip Point					1	7					1	1	1	10	1	10	4
Wedge Island															1	10	1
Chasina Point									1	11							1
Grindall Point											1		1	9			1
Lyman Anchorage												1					1
Windfall Harbor											[1] 1	(?)					1
Doubtful					1	16											1
British Columbia:																	
Wales Island					[3] 3	(?)											3
Mill Bay			[3] 2	(?)	[3] 1	(?)											3
Arrandale					[3] 3	(?)	[3] 1	(?)									4
Steamer Pass															1	4	1
Wark Canal															1	5	1
Chatham Sound															1	3	1
Hyde Bay			1	23													1
Skeena River			1	(?)							1	1			1	(?)	3
Porcher Island							1	18									1
Captain Cove									[4] 1	6(?)							1
Doubtful					[5] 1	(?)	[5] 6	(?)	[5] 1	(?)	[5] 1	(?)			[5] 3	(?)	12
Total	39		43		74		82		72		80		94		105		589
Percentage	25.6		25.9		30.8		35.3		29.6		32.5		40.9		44.1		33.7

[1] Reported as taken before date of tagging.
[2] Includes 2 reported as taken July 22, previous to date of tagging.
[3] Reported as taken during the last four days in July.
[4] Reported taken "about Aug. 1, 1931." Probably taken in 1930 but not reported until 1931.
[5] Reported as taken at Arrandale, Mill Bay, or Wales Island, British Columbia, during the first week in August.

EXPERIMENTS NEAR CAPE FOX

It has been mentioned above that these experiments were undertaken in order to test the extent to which the traps in the region of Cape Fox, and particularly those on Sitklan and Kanaganut Islands, drew upon the salmon runs native to the streams of British Columbia. There are no significant differences in the results of these experiments as compared with the previous experiments conducted in this region in 1924, 1925, and 1926 (loc. cit.). In general a small percentage of the fish were taken in British Columbia although in 1930 the tagging was done chiefly in those traps which were closest to the international boundary. The great majority of the fish tagged were pinks as was also the case in previous experiments. The returns of fish of this species are shown in Table 2.

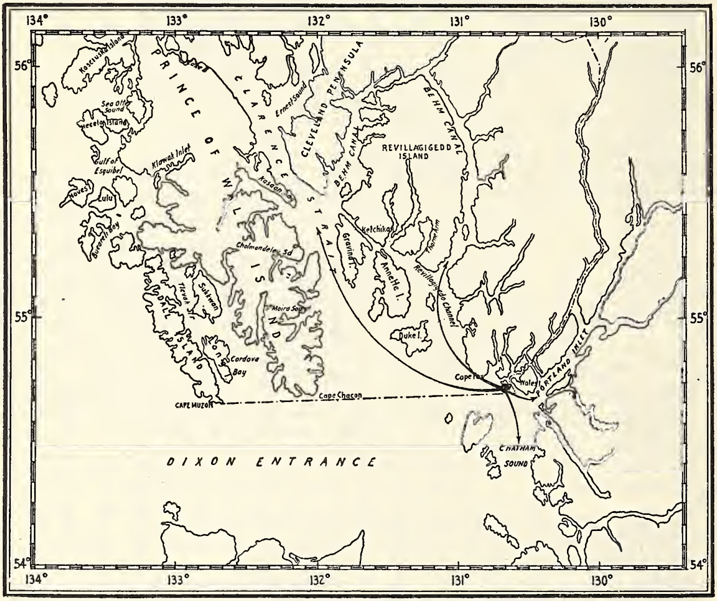

FIGURE 1.—Chief routes of distribution of pink salmon from the region of Cape Fox as shown by the experiments of 1930

The chief route of migration of pink salmon from the region of Cape Fox, Sitklan, and Kanaganut Islands is north in Clarence Strait along the eastern shore and into Revillagigedo Channel. A large number was taken close to the point of tagging as has been a common experience in previous experiments. A fairly large number was taken in Behm Canal, especially near the southern entrance. Comparatively few went across Clarence Strait to the western shore and only 31 out of 589 recaptures (5.3 per cent) were taken in the waters of British Columbia. This is a somewhat smaller percentage than was taken in British Columbia during the course of the ex-

periments in 1925 and 1926. In both of these years approximately 11 per cent of the pinks tagged near Cape Fox was taken below the international boundary. The results are shown graphically in Figure 1.

Comparatively few fish of the other species were tagged during 1930, and the returns were so few that detailed tabulation is unnecessary.

Of red salmon, 109 were tagged and 28 recovered. Of these 6, or 21.4 per cent, came from British Columbia, all being taken in the region of Portland Canal, either at Wales Island, Mill Bay, or Arrandale and were probably bound for the spawning grounds of the Nass River. Considerably larger numbers of red salmon were tagged in previous experiments (especially in 1926, when over 700 were tagged), but the results were much the same. In the experiments of 1924 and 1925 about one-third and in 1926 about 18 per cent of the recaptured reds came from British Columbia waters. In 1930, as in previous years, the reds taken in Alaskan waters were distributed chiefly along the eastern shore of Clarence Strait and in Revillagigedo Channel. Thirteen of the twenty-eight fish recaptured were taken in this region and nine were taken not far from the point of tagging—the others being taken in British Columbia.

Eighty coho salmon were tagged in 1930 near Cape Fox and 13 were recaptured. Six of these were taken in British Columbia waters, of which three came from the region of Portland Canal and one each from Wark Canal, Bulkley River, and Kitemaat River. In 1925 cohos were tagged at Foggy Point in Revillagigedo Channel north of Cape Fox and none was taken in British Columbia, but, in 1926, 238 were tagged near Cape Fox and 41 were returned, of which number about half came from south of the boundary. The results of the tagging in 1930 are much the same, therefore, as those of previous comparable experiments.

One tag attached at Cape Fox on August 7 was reported as placed on a coho, but the fish was recaptured at Metlakatla Bar, British Columbia, on April 20, 1931, and was reported as a king salmon weighing about 32 pounds. In the haste of tagging operations it is not surprising that an error was made in recording the species, but the interesting thing about the record is that, if the fish was small enough on August 7 to be mistaken for a coho, it must have made quite a remarkable growth between that date and the following April. Scales are preserved of all fish tagged and those of this fish have been examined. In certain minor characters they resemble those of the typical silver salmon, but the differences between the scales of silvers and kings are not so well marked that it is possible to distinguish all individual specimens with certainty. In so far as the age of the fish is concerned, however, there can be no doubt that it was a king salmon. It had evidently spent two full years in fresh water, migrating to the sea in the spring of its third year. At the time of tagging it was in its second year in the sea and must have completed this year and started a third year of ocean growth at the time of recapture. Although the silver salmon exhibit some variability as to the length of time spent in fresh water, especially in northern latitudes, they apparently never spend two full years in the sea. There can be little doubt, therefore, that this was a king salmon.

Only 59 chum salmon were tagged near Cape Fox in 1930. Of these, 12 were later recaptured, but only one was taken below the international boundary. This was taken at Wales Island, Portland Canal. The other returns came chiefly from Clarence Strait north of Cape Fox and from Revillagigedo Channel. One was taken in Behm Canal. These results, although meager, are again in substantial agreement with those previously secured. In 1924 and 1925, 67 chums were tagged and 12 recaptured

of which only 1 was taken in British Columbia. In 1926, 3 out of 82 recaptured were taken in British Columbia.

In connection with these experiments at Cape Fox it is interesting to note that the experiments conducted at approximately the same time near Kasaan Bay on the western side of Clarence Strait about 60 miles northwest of Cape Fox yielded only 2 returns from British Columbia—1 coho and 1 red salmon.

In general, the percentage of returns from these experiments was approximately the same as was secured in the experiments of previous years. The percentage of pinks recovered was 33.7 in 1930 and 36.6 in 1924 and 1925. Only a few pinks were tagged in this region in 1926, and the returns were relatively fewer—19 per cent. These last experiments have brought out no important new facts regarding the distribution of fish taken in the traps in the region of Cape Fox but corroborate the conclusion reached in earlier years that by far the larger proportion of the fish taken in Alaskan traps, even those closest to the international boundary, had their origin in Alaskan streams.

EXPERIMENTS NEAR KASAAN BAY

These experiments show quite clearly that the spawning streams of Kasaan Bay contribute an important element to the catches of traps located immediately above and below the entrance to the bay. The evidence on this point seems conclusive in the case of both pinks and chums. In the case of red salmon and cohos the number of returns was too few to warrant definite conclusions, but the indications are that, during the time covered by the experiments, the traps in question did not catch in appreciable quantities fish of these species that were bound for Kasaan Bay.

The returns for pink salmon are given in Table 3.

Table 3.—*Returns from pink salmon tagged near Kasaan Bay*

Locality of recapture	Locality and date of tagging														Total number returned
	South side of entrance to Kasaan Bay, July 29		North of entrance to Kasaan Bay near Windfall Harbor, Aug. 3		North side of entrance to Windfall Harbor, Aug. 3		North side of entrance to Kasaan Bay, Aug. 3		South side of entrance to Kasaan Bay, Aug. 14		North side of entrance to Kasaan Bay, Aug. 14		South side of entrance to Windfall Harbor, Aug. 14		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Clarence Strait—north of Kasaan Bay:															
Streets Island	4	2–8	1	4			4	3–17	3	2–6	5	2–7	2	4	19
Lyman Anchorage							3	3–4			2	3–5	2	3	7
Windfall Harbor			1	4	1	4	1	1	3	1–2	4	2–5	10	2–3	20
Tolstoi Point			1	4	2	4							3	4	6
Narrow Point			1	5	2	5	5	5					1	6	9
Ratz Harbor			[1] 1	(?)											1
Lake Bay							1	11							1
Lemesurier Point			1	4							1	4			2
Myers Chuck											1	3	6	3–6	7
Ship Island													1	5	1
Niblack Point	2	1							2	2	2	3–6			6
Kasaan Bay:															
Grindall Point			2	5–8			2	2	1	4	16	1–8	15	2–6	36
Grindall Island	2	3–6	1	12							18	1–6	4	4–6	25
Kasaan Bay			1	3					3	2					4
Twelve-mile Arm			1	3											1
Skowl Point	8	1–3							10	2–3	7	2–4	1	2	26
Island Point	2	2–3							13	1–6	12	2–5	6	2–5	33
Chasina Point									1	3					1

[1] Reported as taken in the latter part of July.

TABLE 3.—*Returns from pink salmon tagged near Kasaan Bay*—Continued

Locality of recapture	Locality and date of tagging														
	South side of entrance to Kasaan Bay, July 29		North of entrance to Kasaan Bay near Windfall Harbor, Aug. 3		North side of entrance to Windfall Harbor, Aug. 3		North side of entrance to Kasaan Bay, Aug. 3		South side of entrance to Kasaan Bay, Aug. 14		North side of entrance to Kasaan Bay, Aug. 14		South side of entrance to Windfall Harbor, Aug. 14		Total number returned
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Clarence Strait—south of Kasaan Bay:															
Halibut Creek	2	6–9					2	4–13	4	2–4	2	2	1	2	11
Wedge Island									1	2	4	2–4	2	2	7
Rip Point	1	6									1	4			2
Cape Chacon	1	4							15	1–2	2	6	1	6	19
Prince of Wales Island	2	2–19					1	13	2	1	1	2			6
Vallenar Point	1	4	1	6			4	2–5			3	3	3	2	12
Gravina Island	2	1–2	1	1	1	6	3	1–5							7
Bronaugh Island	1	2													1
Annette Island	1	13					1	5							2
Hall Cove	1	13													1
Kah Shakes	1	8													1
Tree Point	1	2													1
Cape Fox							3	4–10	4	2			6	2	13
Cape Fox Island	1	18													1
Doubtful							1	13					3	(?)	4
Cordova Bay, Shipwreck Point	1	22					1	3							2
Behm Canal:															
Camaano Point	1	2									1	5			2
Bond Bay			1	19	1	19									2
Loring			1	18					1	7			1	6	3
Smugglers Cove							3	1							3
Betton Island							1	7							1
Lake McDonald							1	41							1
Point Alava					1	13									1
Point Sykes			2	2–5			2	2–5			2	2			6
Smeaton Bay	1	4													1
Chatham Strait, Point Lull							1	4							1
Total	36		17		8		40		63		84		68		316
Percentage	24.6		12.5		9.2		20.0		46.6		44.0		29.1		27.8

Out of the total of 316 recaptured, 293, or approximately 93 per cent, were taken either in Kasaan Bay or in Clarence Strait. Twenty were taken in Behm Canal and 1 each in Cordova Bay, on the west shore of Prince of Wales Island, and at Point Lull, Chatham Strait. One hundred and twenty-six, or 40 per cent came from Kasaan Bay proper or from fishing operations conducted at the entrance to the bay, and 167 from localities in Clarence Strait both north and south of Kasaan Bay. There appears to be a fairly well-marked difference in the distribution, depending on whether the fish were tagged north or south of the entrance to the bay. Those tagged south of the entrance were taken in greater numbers in the southern part of Clarence Strait, chiefly at localities south of the point of tagging, while those tagged north of the entrance were taken in greater numbers north of the point of tagging. The exact significance of this is not clear, but it seems probable that the difference is due mainly to a general dispersion from the locality where the fish were liberated. It is possible, however, that these results indicate that there is less certainty to the movements of the fish taken south of Kasaan Bay than to those taken north of the bay which are, presumably, nearer the streams to which they are bound. It is also possible, although rather improbable, that the fish taken south of the bay have entered the strait from the north, through Sumner Strait, and are traveling generally toward the south while those taken north of the bay have entered Clarence Strait from the south and are generally traveling northward. Approximately equal proportions crossed Clarence

Strait and were taken on the eastern shore. The fact of chief interest, however, is that from both north and south of the entrance to Kasaan Bay a large percentage of the recaptured fish were taken either in the bay or at its entrance, and it would appear from this that the runs to streams in Kasaan Bay provide an important element in the runs intercepted by traps both north and south of the entrance to the bay.

It is equally certain that the traps in question catch pink salmon that are bound for other localities, but it seems impossible to make any more exact statements than these or to evaluate the extent to which Kasaan Bay fish enter into the catches of the traps just north and south of the entrance of the bay. In order to do this many more fish would have to be tagged, and it would be necessary to have much more detailed information than is available as to the relative fishing effort in the respective localities.

One hundred and eighty-six chum salmon were tagged during the course of the Kasaan Bay experiments. Thirty-six were later recaptured, of which 24 came from the bay, 9 from scattered points in Clarence Strait both north and south of the entrance to the bay, and 1 each from Behm Canal and Sitklan Island. Although the number of returns is small, they indicate clearly the importance of Kasaan Bay as a source of the chums taken in Clarence Strait near the entrance to the bay.

Out of 61 red salmon tagged in this locality 15 were returned. Two of these were taken at Island Point and 1 at Skowl Point in Kasaan Bay. The others were taken at scattered places in Clarence Strait both north and south of the point of tagging and on both sides of the strait and 1 was reported from the Mezidan River in British Columbia. It is apparent that some of the reds caught in this region are native to the streams of Kasaan Bay, but the data are too few to warrant any conclusions as to the extent to which this is true.

One hundred and seventeen cohos were tagged here and 15 were recovered. Of these only 2 were taken in Kasaan Bay, 1 came from Wark Canal in British Columbia, 1 from Behm Canal, 1 from Revillagigedo Channel and the others from various points in Clarence Strait. As in the case of the reds, no definite conclusions can be reached as to the importance of Kasaan Bay cohos in the catch of this species in the traps of Clarence Strait.

CONCLUSIONS

1. The fish taken in the traps in the region of Cape Fox are predominantly native to Alaskan waters and include comparatively small percentages of fish derived from the streams of British Columbia.

2. The catch of the traps in Clarence Strait near the entrance to Kasaan Bay contains fish native to the streams of Kasaan Bay in rather large numbers, but also includes fish bound to other localities in what may be equal or even greater numbers. No reliable evaluation of the proportion of Kasaan Bay fish in these catches can be made with the data at hand.

LIMNOLOGICAL STUDIES OF KARLUK LAKE, ALASKA, 1926–1930[1]

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CONTENTS

Part I. GENERAL LIMNOLOGY

By C. JUDAY, WILLIS H. RICH, and G. I. KEMMERER

INTRODUCTION

The following report deals with the limnological data that were collected on Karluk Lake, Alaska, during the summers of 1926 to 1930, inclusive. In 1926 and 1927 considerable time was spent in making observations on this lake, but from 1928 to 1930 the studies were limited to brief visits in early July each year and again in late August or early September.

These lake studies were made in connection with the general salmon investigations that have been carried on in Alaska for a number of years. These investigations have included a detailed study of the red salmon (*Oncorhynchus nerka*) of Karluk River with the particular object of determining the factors affecting the fluctuations in the size of the runs from year to year. One of the most important of these factors is the size of the breeding populations, as is clearly indicated by the definite periodicity in the size of the runs (Gilbert and Rich, 1927). Beginning in 1921 a weir has been maintained each year in the Karluk River through which the escapement of spawning fish is annually enumerated. These data, together with those of the commercial catch of salmon in the Karluk district, will make possible,

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in time, a fairly reliable determination of the correlation existing between the size of the escapement—that is, breeding population—and the number of the resulting progeny. On *a priori* grounds, however, it could be anticipated that this correlation would not be perfect, since there are various environmental factors which doubtless affect the rate of mortality throughout the life of the salmon from the time the eggs are laid until sexual maturity is reached and the fish return from the sea to spawn. A few clear cut cases are known in which enviromental conditions have destroyed the effect of large spawning escapements. Of the various factors which may affect survival in the ocean we know, at present, very little, but it seems rather probable that conditions in the sea are much more constant than in fresh water. Certainly such factors as the water conditions at the time of spawning and during the incubation period, the abundance of enemies and competitors, and the abundance of natural food organisms in the lakes bear directly upon the ultimate success of breeding.

The Karluk watershed, which is situated in the western part of Kodiak Island, is occupied by the Karluk River, Karluk Lake, Thumb Lake, O'Malley Lake, and a considerable number of tributary streams of various sizes and which together constitute very important breeding grounds for the red salmon. The spawning escapements since 1921 have varied from about four hundred thousand to approximately two and a half millions. Gilbert and Rich (1927) estimated that well over 1,000 million red salmon eggs were deposited in the lakes and streams of this watershed during the spawning season of 1926.

The young red salmon derived from the eggs deposited in this watershed spend some time in Karluk Lake, where they are almost exclusively plankton feeders; they migrate to the sea in the spring of their second to fourth year. The great majority of them leave the lake in the spring of their third year. By far the larger number of them mature in their fifth year and return to spawn at that time, so they spend approximately half of their lives in the lake and half in the sea. The lake, therefore, plays a very important rôle as a nursery for the young red salmon, and this fact has led to a general assessment of its physical, chemical, and biological status. The Karluk system is of special interest in this connection since it is generally recognized that, for its size and the area of its suitable spawning grounds, it is unusually productive. It has maintained a large run over a long period of intense exploitation—a run that is still considered one of the best of the whole of Alaska outside of Bristol Bay where there are numerous streams and lakes all of which are much larger than those of the Karluk system. Those engaged in the salmon investigations at Karluk have spent some time each year on the spawning grounds making such studies of the conditions as were possible in such an isolated locality and with the limited time available. Particular attention has been paid to conditions on the spawning beds, but the obvious importance of a knowledge of conditions in the lakes led to the collection of the data which form the basis of this report.

PHYSICAL AND CHEMICAL DATA

LOCATION AND PHYSICAL FEATURES OF LAKE

Karluk Lake lies in latitude 57° 24′ N. and longitude 154° 5′ W. The lake is long, narrow, and straight sided, with a prominent bay, the Thumb, situated about the middle of the east side. (See fig. 1.) Three small islands help to separate the Thumb from the main part of the lake. The main axis of the lake lies in a general north and south direction and its maximum length is 19.6 kilometers (12.2 miles);

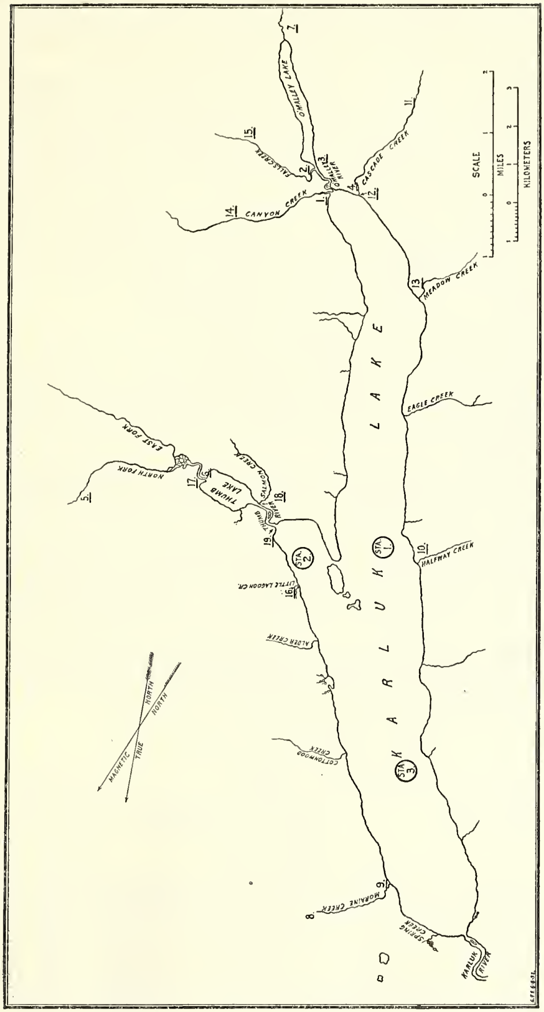

FIGURE 1.—Map of Karluk Lake region, Kodiak Island, Alaska

the greatest width is 3.1 kilometers (2 miles). The area is 39.5 square kilometers (15.2 square miles) and the maximum depth is 126 meters (413 feet). The mean depth is 48.6 meters (159 feet). The surface of the lake is about 106 meters (350 feet) above sea level, so that the deepest part of the basin is about 20 meters (65 feet) below sea level.

The lake is surrounded by mountains which rise to a height of 760 meters (2,500 feet) and the immediate shores consist of shale with an occasional small ledge or vein of quartz. The lake basin appears to be of recent glacial origin and the water is impounded by a large terminal moraine at the north end. In general, the beaches are composed of gravel and bowlders of various sizes. The shores are still in a youthful stage and the subaqueous terrace is poorly developed; as a result the bottom slopes away abruptly from the shores. The outlet, the Karluk River, flows out of the north end of the lake; it is a stream of considerable size and it is about 48 kilometers (30 miles) long (Gilbert and Rich, 1927). A rough estimate of the quantity of water discharged into Karluk Lake by the more important tributary streams was placed at 7 cubic meters per second in late August 1928.

The narrow subaqueous terrace and the steep slope of the bottom make conditions unfavorable for the growth of the large aquatic plants along most of the shore; such growths are found in only three favorable localities. Filamentous algæ are found in considerable abundance on submerged rocks and bowlders along the margin of the lake. The shores are well covered with groves of cottonwoods, alders, birches, willows, and shrubs.

Thumb Lake is situated about the middle of the east side of Karluk Lake (fig. 1); it is about 1 kilometer (¾ mile) long and half a kilometer (⅜ mile) wide. Its maximum depth is 10 meters (33 feet). A short stream known as the Thumb River connects Thumb Lake with Karluk Lake.

O'Malley Lake is situated at the south end of Karluk Lake; it is about 3 kilometers (2 miles) long and ⅓ of a kilometer (⅕ mile) wide. It has a maximum depth of 12 meters (40 feet); and its outlet, the O'Malley River, flows into the south end of Karluk Lake.

Gilbert and Rich (1927) published a hydrographic map of Karluk Lake which was based on surveys and soundings made in the summer of 1926. The data concerning the area and the volume of the lake, which are given in Table 1, are based upon measurements of the original map prepared by these authors.

TABLE 1.—*Area and volume of Karluk Lake*

Depth in meters	Areas: Square kilometers	Areas: Square miles	Per cent of total area	Stratum	Volume: Million cubic meters	Volume: Million cubic yards	Per cent of total volume
0	39.5	15.2	100.0	0–10	374.3	489.6	19.50
10	35.4	13.7	89.6	10–20	334.7	437.8	17.44
20	31.6	12.2	80.0	20–30	288.9	377.9	15.06
30	26.3	10.1	66.6	30–40	230.9	302.0	12.02
40	20.2	7.8	51.1	40–50	173.2	226.5	9.02
50	15.4	5.9	39.0	50–60	121.2	158.5	6.31
60	11.0	4.2	27.8	60–70	102.4	133.9	5.33
70	9.5	3.7	24.0	70–80	86.9	113.7	4.52
80	7.9	3.0	20.0	80–90	70.8	92.6	3.69
90	6.3	2.4	16.0	90–100	55.3	72.3	2.88
100	4.8	1.8	12.1	100–110	42.9	56.1	2.23
110	3.8	1.5	9.6	110–120	32.9	43.0	1.71
120	2.8	1.1	7.1	120–126	5.6	7.3	0.29
					1,920.0	2,511.2	100.00

TRANSPARENCY OF WATER

The transparency of the water was measured by means of the Secchi disk. The results of the readings in the three lakes are given in Table 2. In general, the water of Karluk Lake was more transparent than that of Thumb and O'Malley Lakes. Thumb Lake was the least transparent of the three. Karluk Lake was more transparent in 1928 than in either of the other years represented in the table.

TABLE 2.—*Transparency of the water in Karluk, Thumb, and O'Malley Lakes*

[The readings of the Secchi disk are indicated in meters and they show the depth at which the disk disappeared from view]

Karluk Lake		Thumb Lake		O'Malley Lake	
Date	Depth	Date	Depth	Date	Depth
July 10, 1928	8.6	July 9, 1928	2.5	July 10, 1929	5.5
Sept. 3, 1928	8.0	Sept. 3, 1928	3.0	Sept. 12, 1929	3.8
July 9, 1929	5.5	July 11, 1929	2.8	July 15, 1930	4.0
Sept. 7, 1929	4.5	Sept. 7, 1929	2.5	Sept. 5, 1930	4.0
July 12, 1930	7.5	July 13, 1930	2.6		
Sept. 9, 1930	7.8	Sept. 6, 1930	2.0		

TEMPERATURES

The climate of Kodiak Island, on which Karluk Lake is situated, is temperate. The lake lies in the Pacific coast climatic zone of Alaska, and this region possesses a marine climate, with a large amount of cloudy weather. There is no permanent settlement in the vicinity of Karluk Lake, and the nearest weather-observing station is located at the village of Kodiak on the eastern end of Kodiak Island, about 160 kilometers (100 miles) from the lake. Table 3 shows the range of variation of atmospheric temperatures at Kodiak from 1926 to 1930, inclusive, as well as the mean temperature for these years. The United States Weather Bureau reports that temperatures were above normal throughout the year in 1926 at nearly all Alaskan stations, considerably exceeding all previous records. The mean annual temperature was about normal in 1927 and 1930 and just a little above normal in 1928 and 1929.

TABLE 3.—*Range of air temperatures at Kodiak on Kodiak Island, Alaska, during the years 1926–1930, inclusive, and the mean annual temperature for these five years*

Year	Maximum		Minimum		Mean annual	
	°C.	°F.	°C.	°F.	°C.	°F.
1926	25.5	78	−12.2	10	7.3	45.1
1927	20.0	68	−13.3	8	4.6	40.3
1928	22.2	72	−15.6	4	5.2	41.4
1929	27.8	82	−11.6	11	6.2	43.2
1930	27.2	81	−16.7	2	4.7	40.5

The mean monthly temperature was lowest in February, 1926, being 0.5° C. or 33° F., but December was almost as low, namely, 0.7° C. or 33.2° F. The mean monthly temperature was lowest in March from 1927 to 1929; it was −1.8° C. (28.7° F.) in 1927, −1.3° C. (29.7° F.) in 1928, and −0.3° C. (31.4° F.) in 1929. February had the lowest mean in 1930, namely, −5.3° C. (22.5° F.). The monthly mean was highest in August in 1926 to 1928, inclusive; it was 13.7° C. (56.6° F.) in 1926, 11.7° C. (53° F.) in 1927, and 12° C. (53.4° F.) in 1928. In 1929 the monthly means were the same for July and August, namely, 13.2° C. (55.8° F.). It was highest in August, 1930, namely, 13.5° C. (56.3° F.).

The total precipitation at the Kodiak weather station was 195.8 centimeters (77.08 inches) in 1926; 151 centimeters (59.47 inches) in 1927; 167.1 centimeters (65.79 inches) in 1928; 135.7 centimeters (53.42 inches) in 1929; and 119.3 centimeters (46.99 inches) in 1930.

Karluk Lake is usually covered with ice in winter; it freezes over during the latter part of December and opens again some time in April. In 1931 the lake became free of ice on April 20. In very mild winters, such as that of 1925–26, the lake does not freeze, but this is reported to happen only once in about 20 to 25 years.

Table 4 shows the results of the temperature readings obtained at station 1, which is situated in the deepest part of Karluk Lake. The surface temperature ranged from

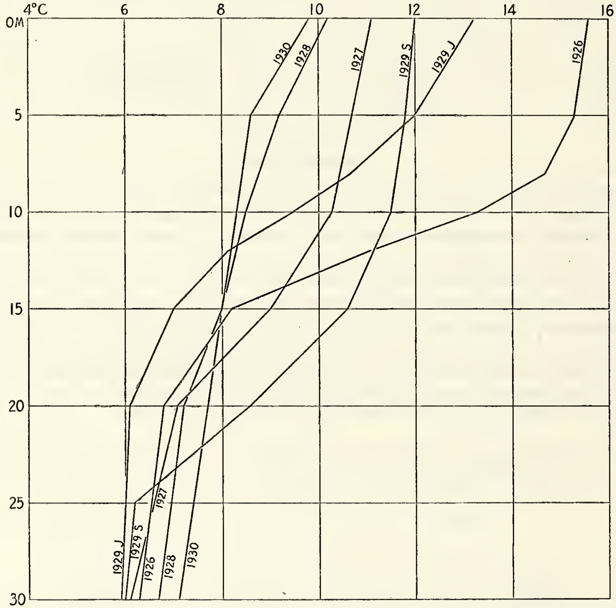

FIGURE 2.—Summer temperatures of the upper 30 meters of Karluk Lake, 1926 to 1930, inclusive. The series shown in the diagram were taken as follows: August 15, 1926; August 13, 1927; July 10, 1928; July 9, 1929 (*J*); September 8, 1929 (*S*); July 12, 1930. The temperatures are indicated in degrees centigrade. Note the definite stratification in 1926

about 10° C. (50° F.) in early July to a maximum of 15.6° C. (56° F.) about the middle of August; the highest temperatures were found during the warm summer of 1926. In this year the three thermal strata of the lake were well marked. The epilimnion extended from the surface to a depth of about 8 meters on August 15, 1926; the thermocline extended from 8 to 15 meters and the hypolimnion from the latter depth to the bottom. The epilimnion and thermocline were not so definitely outlined in the other years.

Six sets of the temperature readings for the upper 30 meters are shown in Figure 2. The readings taken on July 12, 1930, show the lowest surface temperature and those

of August 15, 1926, the highest. The curve for 1926 shows that the epilimnion and the thermocline were more sharply defined in that year than in the other years. At a depth of 30 meters the highest temperature (7.1° C.) was noted on July 12, 1930, and the lowest (5.9° C.) on July 9, 1929. The two curves for 1929 show the temperature changes which took place in the upper 30 meters of water between July 9 and September 8 of that year. Between these two dates there was a decrease in the temperature of the upper 5 meters; but there was a marked rise in temperature between 5 and 25 meters, with a slight increase between the latter depth and 30 meters. The bottom temperatures in the deepest water of Karluk Lake ranged from a minimum of 4.1° C. (39.4° F.) to a maximum of 4.9° C. (40.8° F.). (Table 4.)

TABLE 4.—*Summer temperatures of Karluk Lake at station 1*

[The readings are indicated in degrees centigrade at the different depths]

Depth in meters	Aug. 15, 1926	July 19, 1927	Aug. 13, 1927	July 10, 1928	Sept. 3, 1928	July 9, 1929	Sept. 8, 1929	July 12, 1930
0	15.6	11.3	11.1	10.2	9.7	13.2	12.0	9.8
5	15.3	11.0	-----	9.2	9.7	12.0	11.8	8.6
8	14.7	9.7	-----	-----	-----	10.7	-----	-----
10	13.5	9.7	10.3	8.5	9.7	9.5	11.5	8.3
12	11.1	8.4	-----	-----	-----	8.1	-----	-----
15	8.2	7.2	9.0	8.0	9.7	7.0	10.6	8.0
20	6.8	6.2	7.1	7.2	8.6	6.1	8.6	-----
25	-----	-----	-----	6.6	8.3	-----	6.2	-----
30	6.3	-----	6.1	-----	-----	-----	-----	7.1
50	6.0	-----	-----	5.6	6.9	-----	-----	5.6
126	4.9	4.2	4.4	4.4	4.9	4.1	4.8	4.2

No winter temperatures have been taken in Karluk Lake, so that the winter minimum is not known definitely. Some observations made in the spring of 1931, however, serve as a basis for estimating the minimum. The covering of ice disappeared from Karluk Lake on April 20, 1931, while the ice disappeared from the lakes of northeastern Wisconsin on April 13 to 15, 1931, or only about a week earlier than on Karluk. On May 2, 1931, the temperature of the surface water of Karluk Lake was 2.4° C. (36.3° F.) and that at 126 meters was 2.6° C. These results are similar to those obtained on Wisconsin lakes soon after the disappearance of the ice, and it seems probable that the temperature cycle in Karluk Lake is substantially the same in winter as that of the Wisconsin lakes where the mean temperature at the time of freezing is about 1° C. Thus a minimum temperature of 1° C. may be used for the computation of the heat budget of Karluk Lake. The summer heat income represents the gain above a temperature of 4° C.

Table 5 shows the annual heat budget, the summer heat income, and the gain in heat which took place between the two sets of summer temperature readings in three of the years in which observations were made. The heat budgets represented in the table ranged from 28,200 gram-calories per square centimeter of surface on July 19, 1927, to 35,800 gram-calories on August 15, 1926. At the time of the July observations in 1927 to 1929, inclusive, the heat budgets amounted to 28,000 to 29,000 gram-calories per square centimeter and a further gain of 2,400 to 5,800 calories was made between the July readings and those of August or September. The heat budgets indicated for September 3, 1928, and September 8, 1929, probably represent the maximum budgets for those years as it does not seem probable that the water gained any heat after these dates. The budgets for August 15, 1926, and August 13, 1927, may not represent the maximum for those years, but the gain in heat after the middle of August is probably small in that latitude, except perhaps in years when it is unusually warm in the latter half of August and in early September.

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The summer heat income ranged from 16,000 calories on August 13, 1927, to 21,200 calories on August 15, 1926. The mean summer heat income for the four August and September observations is 18,900 calories.

The gain of 5,800 gram-calories between July 10 and September 3, 1928, represented an average daily gain of a little more than 105 gram-calories for this period of 55 days. The gain between July 19 and August 13, 1927, was about 96 calories per day, while that between July 9 and September 8, 1929, was only 68 calories per day.

TABLE 5.—*The mean temperature, heat budget, summer heat income, and gain in heat between the two dates on which summer temperature observations were made on Karluk Lake*

[The results for heat are indicated in gram-calories per square centimeter of surface]

Date	Mean temperature, °C.	Heat budget	Summer heat income	Gain in heat	
				Total	Average per day
Aug. 15, 1926	8.37	35,800	21,200		
July 19, 1927	6.80	28,200	13,600		
Aug. 13, 1927	7.30	30,600	16,000	2,400	96
July 10, 1928	6.84	28,400	13,800		
Sept. 3, 1928	8.03	34,200	19,600	5,800	105
July 9, 1929	7.02	29,200	14,600		
Sept. 8, 1929	7.87	33,400	18,800	4,200	68
July 12, 1930	7.00	29,100	14,500		

The mean of the August and September heat budgets of Karluk Lake in 1926 to 1929, inclusive, is 33,500 gram-calories. This budget is comparable in size to those of a number of lakes situated in much lower latitudes, such as Green Lake, Wis., and some of the Finger Lakes of New York, as well as some of the European lakes. The heat budgets of several American and European lakes are given in Table 6.

These data show that the average heat budget of Karluk Lake is exceeded somewhat by those of some of the larger lakes represented in the table, such as Seneca, Cayuga, and Owasco of New York, Geneva of Switzerland, and Loch Ness of Scotland, but the 1926 budget of Karluk almost or quite reaches that of some of the members of this group. The averages for Karluk and Green Lake are substantially the same, as well as that of Traun See of Austria. Four of the lakes included in the table have smaller heat budgets than Karluk Lake. While the temperature of the upper water of Karluk Lake is not as high as that of Green Lake, Wis., and of the Finger Lakes of New York, yet its area and depth are such that it absorbs a similar amount of heat per unit of area during the warming period each year, as indicated in the table.

TABLE 6.—*Heat budgets of some American and European lakes*

Lake	Location	Heat budget, gram-calories	Lake	Location	Heat budget, gram-calories
Karluk	Alaska	33,500	Zürich	Switzerland	21,800
Green	Wisconsin	34,000	Würm	Germany	26,000
Seneca	New York	36,700	Traun	Austria	33,400
Cayuga	do	37,400	Vettern	Sweden	32,000
Owasco	do	35,600	Ness	Scotland	37,200
Geneva	Switzerland	36,600	Lochy	do	31.500

Table 7 shows the results of the temperature readings on Thumb and O'Malley Lakes. The surface temperatures of these two lakes did not differ greatly from those of Karluk Lake on corresponding dates; the maximum difference was noted in 1929 when the surface water of O'Malley Lake had a temperature of 16° C. (60.8° F.) on July 10 and that of Karluk Lake was 13.2° C. (55.8° F.) on July 9. The maximum difference between surface and bottom temperatures in Thumb Lake was 4.2° C. on July 11, 1929, and a difference of 4° C. was noted in O'Malley Lake on July 10, 1929.

TABLE 7.—*Summer temperatures of Thumb and O'Malley Lakes*

[The readings are indicated in degrees centigrade]

Thumb Lake			O'Malley Lake		
Date	Depth in meters	Temperature	Date	Depth in meters	Temperature
July 21, 1927	0	11.8	July 23, 1927	0	13.1
Do	10	10.0	Do	12	12.8
Aug. 3, 1927	0	12.0	Aug. 10, 1927	0	13.2
Do	10	10.4	Do	12	12.2
July 9, 1928	0	10.7	July 10, 1929	0	16.0
Do	10	8.1	Do	12	12.0
Sept. 3, 1928	0	8.2	Sept. 12, 1929	0	13.2
Do	10	7.4	Do	12	12.4
July 11, 1929	0	10.3	July 15, 1930	0	13.4
Do	10	6.1	Do	12	13.0
Sept. 12, 1929	0	12.4	Sept. 5, 1930	0	14.9
Do	10	10.2	Do	12	14.8
July 13, 1930	0	10.4			
Do	10	8.3			
Sept. 6, 1930	0	12.7			
Do	10	10.1			

CHEMISTRY OF LAKES

Table 8 shows the results of the chemical analyses that were made on the waters of Karluk, Thumb, and O'Malley Lakes during July and August, 1927. In Karluk Lake the hydrogen-ion concentration ranged from pH 8.6 at the surface to pH 7.0 at a depth of 120 meters. In Thumb Lake the hydrogen-ion readings were somewhat lower, ranging from pH 8.2 at the surface to pH 6.8 at the bottom, while in O'Malley Lake the readings were still lower, being pH 8.0 at the surface and pH 6.6 at the bottom.

In Karluk Lake the free carbon dioxide amounted to 1 milligram per liter of water at the surface and to 3.5 to 4 milligrams at the bottom. In both Thumb and O'Malley Lakes the free carbon-dioxide content was somewhat larger in the bottom water than in the main basin of Karluk Lake, but the quantity found in the lower water of the Thumb Basin of Karluk Lake on August 2, 1927, was a little greater than that in the lower water of Thumb Lake. The fixed or bound carbon dioxide in Karluk Lake varied between 9 and 10 milligrams per liter of water and O'Malley Lake had the same amount; the quantity was a little larger in Thumb Lake, namely 11 to 12 milligrams per liter. This relatively small quantity of fixed carbon dioxide indicates that these waters contain correspondingly small amounts of carbonates in solution, and this comparatively small carbonate content is due to the fact that the country rock of this drainage basin consists chiefly of slate.

TABLE 8.—*Results of chemical analyses of the waters of Karluk, Thumb, and O'Malley Lakes in 1927*

[The results are stated in milligrams per liter of water, Tr.=trace]

Date, 1927	Depth in meters	Temperature, °C.	pH	Carbon dioxide		Oxygen	Phosphorus			Silica	Nitrogen		
				Free	Fixed		Soluble	Organic	Total		Ammonia	Nitrite	Nitrate
KARLUK LAKE, STATION 1													
July 19	0	11.3	8.4	1.0	9.5		0.002	0.004	0.006	0.0	0.008		
Do	120	4.2	7.0	4.0	9.0	11.3				.6	.040	Tr.	0.030
July 31	0	11.4	8.2	1.0	9.5		.002	.003	.005	.5	.000		.012
Do	13	8.9	8.0	1.0			.002			.5			
Do	122	4.3	7.6	2.0			.010						
Do	125	4.3	7.5	3.5	9.5	12.1	.010			.5	.050	.001	.052
Aug. 13	0	11.1	8.2	1.0	9.5		.002	.028	.030	0	.004	.000	
Do	125	4.4	7.5	3.5	9.5		.008	.014	.022	.5	.022	.000	
KARLUK LAKE, STATION 2 (THE THUMB)													
July 20	0	11.2	8.2	1.0	9.5		.002	.003	.005				
Do	40	5.5	7.2	3.5	10.0	8.8	.010						.020
Aug. 2	0	11.2	8.2	1.0			.002	.018	.020	0	.000	.000	.035
Do	10	10.8	8.0	1.5			.003	.022	.025	0	.030	.000	.035
Do	41	5.5	7.4	3.5			.006	.014	.020	0	.060	.000	
Do	42.5	5.5	7.2	8.5		9.6	.015			.5	.120	.000	.050
Aug. 12	0	11.0	8.6	0	10.0		.002				Tr.	.000	
Do	40	5.6	7.6				.010						
Do	41.5	5.6	7.2	2.5	10.0		.018	.012	.030		.080	Tr.	
THUMB LAKE													
July 21	0	11.8	8.2	1.5	10.5		.004	.006	.010	.5	.040	.002	.012
Do	10	10.0	6.8	7.5	10.5	6.3	.020	.022	.042	1.0	.250	.002	.018
Aug. 3	0	12.0	8.2	2.0	11.5		.004	.016	.020	0	.064	.000	.050
Do	10	10.5	6.8	6.5	11.0		.020	.020	.040	1.0	.400	.005	.060
Aug. 12	0	11.1	8.0	2.0	11.5		.006	.044	.050	.5	.032	.001	
Do	3		7.8	1.5			.004						
Do	5		7.6	2.5	11.5		.012	.033	.045	.5	.040	.001	
Do	10	9.7	7.0	5.0	12.0		.070	.022	.092	2.0	.400	.001	
O'MALLEY LAKE													
July 23	0	13.1	7.2	1.5	10.0		.003	.044	.047	0	.008	.000	.056
Do	12	12.8	6.6	3.0	10.0	6.3	.007	.041	.048	.5	.084	.000	.052
Aug. 10	0	13.2	8.0	1.5	9.0		.003	.032	.035	1.0	Tr.		
Do	11	12.2	7.4	2.8	9.5	10.5	.005	.035	.040	1.5	.020		
BOG POND													
July 30	0	17.0	7.8	2.5	11.0		.000			1.5	.000		

No complete series of dissolved oxygen determinations was made, but samples were obtained from the bottom water of each of the three lakes. At station 1 in the deepest water of Karluk Lake the lower water was well supplied with dissolved oxygen; the quantity ranged from 85 to 92 per cent of the amount required for saturation. A smaller amount was found in the lower water of The Thumb Basin of Karluk Lake; here the amount reached only 69 to 72 per cent of saturation. A still smaller amount was found in the bottom waters of Thumb and O'Malley Lakes where the quantity reached only 55 and 58 per cent of saturation, respectively. In spite of the lower percentages in the latter lakes, the lower water of all three lakes was well supplied with dissolved oxygen, so that all three of them belong to the oligotrophic type.

The quantity of soluble phosphorus in the surface water of Karluk Lake was 0.002 milligram per liter. In Thumb Lake it varied from 0.004 to 0.006 milligram per liter and in O'Malley Lake it was 0.003 milligram per liter. The amount of soluble phos-

phorus was larger in the lower water than in the surface water in all cases. This is due to the decomposition of organic matter in the lower stratum. The plankton and other organic material which settles into the lower water and decomposes there contains organic phosphorus which is changed to the soluble form during the decomposition process. As a result of this change the soluble phosphorus shows a more or less marked increase in quantity in the lower water during the summer; the extent of this increase is dependent upon the amount of organic matter which decomposes in this stratum.

The organic phosphorus consists of that part of this element which is combined with the organic matter that is present in the water in the form of living organisms, or in organic material derived from such organisms. The quantity of organic phosphorus is dependent upon the amount of organic matter, but the former is not directly proportional to the latter. The various organic compounds possess different percentages of phosphorus, so that there is no direct quantitative relation between the two. The quantity of organic phosphorus is usually larger than that of the soluble phosphorus; frequently the former is several times as large as the latter, as shown in the surface water of Karluk Lake on August 13, 1927. In the bottom water, however, the quantity of soluble phosphorus may be several times as large as that of the organic phosphorus; the 10-meter sample of Thumb Lake on August 12, 1927, contained more than three times as much soluble as organic phosphorus. In Karluk Lake there was only half as much organic phosphorus in the 125-meter sample as in the surface sample on August 13, 1927. A similar result was obtained in Thumb Lake on August 12, 1927; on July 21, however, there was a larger amount of organic phosphorus in the lower than in the upper water of this lake.

The quantity of titratable silica in the waters of the three lakes varied from none to 2 milligrams per liter. This substance is used by the diatoms in making their siliceous shells, so that the quantity of silica in the water is correlated more or less closely with the growth of these organisms. A large crop of diatoms may completely exhaust the supply of available silica as shown in some of the surface samples of these three lakes. The largest amounts of silica were found in the lower water where light conditions were unfavorable for the growth of diatoms. The plankton contained a rather large number of diatoms, so there was an active demand for silica in the upper water.

Only small amounts of ammonia nitrogen were found in the upper waters of the three lakes, but larger amounts were obtained from bottom samples. The activities of the phytoplankton in the upper strata create a demand for nitrogen, and free ammonia can be used by these organisms as well as nitrite and nitrate nitrogen. This accounts for the small amount of ammonia nitrogen in the upper water. The free ammonia of the lower water is derived from the organic matter which decomposes in that region; since light conditions are unfavorable for photosynthesis there is no demand for the ammonia nitrogen in the lower strata.

Only a very small amount of nitrite nitrogen was found at any depth. In Karluk Lake the nitrate nitrogen varied from 0.02 to 0.052 milligram per liter, the largest amount being found in the bottom water. The waters of Thumb and O'Malley Lakes yielded from 0.012 to 0.06 milligram of nitrate nitrogen per liter.

Two liter samples of surface and bottom water from Karluk Lake were evaporated in July and September, 1930, and the residues obtained from them were analyzed for various constituents. Residues were obtained from surface samples of Thumb and O'Malley Lakes also. The results of these analyses are given in Table 9.

The residues obtained from the Karluk samples of water ranged from a little more than 30 to 34 milligrams per liter. The surface and bottom samples yielded nearly the same amounts of residue in the four sets taken in 1930. The residues from O'Malley Lake were somewhat smaller than those from Karluk Lake. While the July sample from Thumb Lake was about the same as those from Karluk Lake, the September sample from the former was distinctly larger than those of the latter.

The quantity of silica was substantially the same in Karluk and Thumb Lakes, but a somewhat larger amount was found in the O'Malley samples. The amount of calcium was approximately the same in the three lakes. but the September sample from Thumb Lake yielded a somewhat larger quantity than any of the others. The quantity of magnesium also was not very different in the various samples; in general the amount of magnesium was somewhat smaller than that of calcium. The quantity of phosphorus was about the same in Karluk and O'Malley Lakes, but about twice as much was found in the Thumb Lake samples as in those from the other two lakes. This extra quantity of phosphorus in Thumb Lake was undoubtedly derived from the decomposing carcasses of the red salmon.

TABLE 9.—*Chemical analyses of residues from Karluk, Thumb, and O'Malley Lakes*

[The results are indicated in milligrams per liter of water]

Lake	Date, 1930	Depth in meters	Residue	SiO_2	Ca	Mg	Total P
Karluk Lake, station 1 (upper basin)	July 12	0	31.5	1.7	5.62	4.42	0.016
	do	125	33.4	1.9	5.48	5.91	.016
	Sept. 2	0	30.5	1.5	5.58	5.36	.019
	do	125	30.3	1.6	4.80	5.34	.015
Karluk Lake, station 2 (the Thumb)	July 12	0	34.0	2.0	5.82	3.46	.018
	July 13	43	32.0	1.8	6.21	4.35	.018
	Sept. 3	0	32.1	1.7	5.76	5.44	.014
	Sept. 2	43	30.9	1.6	5.11	5.00	.016
Thumb Lake	July 13	0	31.4	1.8	5.90	5.62	.028
	Sept. 6	0	38.3	1.9	7.16	6.53	.039
O'Malley Lake	July 15	0	28.5	2.7	5.92	4.86	.015
	Sept. 5	0	29.8	2.9	6.15	4.55	.014

CHEMISTRY OF STREAMS

The results of the temperature and chemical observations that were made on 10 affluents of Karluk Lake during the summer of 1927 are shown in Table 10. The temperature of the water in these streams was lower than that of the surface water of Karluk Lake during that season. In the various streams the temperature ranged from a minimum of 4.2° C. (39.5° F.) in Little Lagoon Creek on July 29, 1927, to a maximum of 13° C. (55.4° F.) in O'Malley River on July 17, 1927. The surface temperature of Karluk Lake in 1927 varied from 11° C. (51.8° F.) to 11.4° C. (52.5° F.). All of the streams are relatively short and have rapid currents, so that the water is not warmed very much on its way to the lake. (See fig. 1.)

The hydrogen-ion concentration of the stream waters varied from pH 6.8 to pH 8.0, while that of the surface water of Karluk Lake was more alkaline, ranging from pH 8.2 to pH 8.6.

The free carbon dioxide of the stream waters varied from a minimum of 1 milligram to a maximum of 6.5 milligrams per liter, while the average amount in the surface water of Karluk Lake was 1 milligram per liter. In general the stream waters yielded a somewhat larger amount of fixed or bound carbon dioxide than the surface water of Karluk Lake. They contained from 10.5 to 12 milligrams per liter, with a

maximum of 22 milligrams in one stream; the surface water of the lake yielded from 9.5 to 10 milligrams of fixed carbon dioxide per liter. The 22 milligrams per liter found in Little Lagoon Creek was about twice the amount present in the other streams. This indicates that there is a much larger quantity of calcareous material in the drainage basin of this stream than in those of the other streams.

TABLE 10.—*Results of the chemical analyses of the stream waters*

[Results are stated in milligrams per liter of water. Tr. means trace. The station numbers are indicated on the map, fig. 1]

No.	Stream	Locality	Date, 1927	Temperature °C.	pH	Carbon dioxide		Phosphorus			Silica	Nitrogen		
						Free	Fixed	Soluble	Organic	Total		Ammonia	Nitrite	Nitrate
1	Canyon Creek	At lake	July 17	7.5	7.7	1.2	11.7	0.008	0.032	0.040	3.0	0.084		0.015
2	Falls Creek	At mouth	do	8.0	7.6	1.2	11.5	.005	.003	.008	3.0	.056		.015
3	O'Malley River	Above Falls Creek	do	13.0	8.0	1.0	12.0	.004	.020	.024	1.0	.021		.008
4	Cascade Creek	At lake	do	7.5	8.0	1.2	12.0	.005	.011	.016	3.5	.052		.010
5	Upper Thumb River	North fork above falls.	July 21	8.9	7.6	2.2	10.0	.004	.006	.010	2.2	Tr.	0.000	.005
6	do	At Thumb Lake	do		7.2	6.5	10.5	.025	.015	.040	2.0	.328	.018	.060
7	Upper O'Malley River.		July 23		7.4	2.5	10.5	.002	.030	.032	2.0	.020	.000	.072
8	Moraine Creek	Upper end	July 25		7.4	2.0	11.0	.004	.018	.022	2.0	.000	.000	.040
9	do	At lake	do	7.5	7.0	5.0	11.0	.060	.130	.190	2.0	.400	.009	.085
10	Halfway Creek	do	do	7.9	6.9	3.5	10.0	.023	.032	.055	2.0	.160	.005	.042
11	Cascade Creek	At falls	July 27	8.3	8.0	2.0	11.5	Tr.	.003	.003	3.0	Tr.		.040
12	do	At lake	do	8.3	7.8	3.5	12.0	.016			2.0	.080	.004	.030
13	Meadow Creek	do	do	9.5	7.6	4.0	10.5	.030	.005	.035	3.0	.220	.008	.050
14	Canyon Creek	Above falls	July 29	8.0	7.6	2.5	12.0	.002	.016	.018	1.5	Tr.		.020
15	Falls Creek	do	do	9.2	7.8	2.5	11.5	.003	.019	.022	1.5	Tr.		.020
16	Little Lagoon Creek	Above Salmon	do	4.2	7.8	2.5	22.0	.005	.025	.030	2.0	Tr.		.040
17	Upper Thumb River	At lake	Aug. 3	8.3	6.8	4.5	11.0	.019			2.0	.280	.010	.060
18	Salmon Creek	At Thumb River	do	7.2	7.2	4.5	11.5	.005	.010	.015	1.5		.005	
19	Thumb River	At Karluk Lake	Aug. 13	10.0	7.8	3.0	11.0	.015	.020	.035	1.5	.080	.001	

Most of the streams carried a larger quantity of phosphorus, both soluble and organic, than the surface water of Karluk Lake. There was also a marked difference in the amount of phosphorus found in the different streams. The soluble phosphorus varied from only a trace in Cascade Creek at the falls to a maximum of 0.06 milligram per liter in Moraine Creek at the lake. The organic phosphorus ranged from a minimum of 0.003 milligram in Falls and Cascade Creeks to a maximum of 0.13 milligram per liter in Moraine Creek at the lake.

There was also a marked difference in the quantity of both soluble and organic phosphorus in the upper courses and in the lower courses of several streams. Such differences are shown in Table 10 for Canyon Creek, Cascade Creek, Moraine Creek, and the Upper Thumb River. The stations at which the various samples were taken are indicated on Figure 1. The water at the mouth of Moraine Creek yielded 15 times as much soluble phosphorus as that at the upper end of this stream and 7 times as much organic phosphorus. The quantity of soluble phosphorus was more than six times as large at the mouth of the Upper Thumb River as it was above the falls in the north fork of this stream. The differences in Canyon and Cascade Creeks were not as marked as those in the other two streams indicated above, while a smaller quantity of phosphorus was found at the mouth of Falls Creek than at the station above the falls in that stream.

The titratable silica in the various streams ranged from 1 to 3.5 milligrams per liter of water. This quantity was larger than that in the upper water of Karluk Lake.

In general, much larger amounts of ammonia, nitrite, and nitrate nitrogen were found in the stream waters than in the surface water of Karluk Lake; also considerable

differences were noted in the different streams, as well as between the upper and lower courses of the individual streams. The maximum quantity of ammonia nitrogen was found in the sample obtained at the mouth of Moraine Creek on July 25, 1927, namely 0.4 milligram per liter of water; the next in rank was a sample from the mouth of Upper Thumb River which contained 0.328 milligram of ammonia nitrogen per liter. The smallest amounts of free ammonia were found in the upper courses of some of the streams, such as none in the upper part of Moraine Creek and only traces in the upper parts of Canyon, Falls, and Little Lagoon Creeks, and the north fork of Upper Thumb River.

The maximum quantity of nitrite nitrogen was found at the mouth of Upper Thumb River, namely 0.018 milligram per liter, while none was found in the samples taken in the upper courses of three streams. The other samples on which determinations were made yielded from 0.001 to 0.01 milligram of nitrite nitrogen per liter.

The largest amount of nitrate nitrogen found in the stream waters was obtained at the mouth of Moraine Creek, namely 0.085 milligram per liter. In the other stream samples the quantity of nitrate nitrogen ranged from 0.005 milligram in the north fork of the Upper Thumb River to 0.072 milligram per liter in Upper O'Malley River. In Canyon, Cascade, and Falls Creeks there was a somewhat larger amount of nitrate nitrogen in the samples from the upper courses than in those from the mouths of these streams. In Moraine Creek, on the other hand, there was a little more than twice as much nitrate nitrogen in the sample obtained from the mouth as in that from the upper course of this stream. In the Upper Thumb River there were 12 times as much in the sample taken at the mouth as in that taken in the north fork of this stream above the falls.

The red salmon which come into these lakes and streams to spawn have a very important effect upon the chemical status of their waters. After spawning these salmon die and the carcasses decompose either in the water or along the shores of the lakes and streams. The greater part of this decomposition takes place in the streams. In an average year more than a million red salmon, each weighing from 2 to 3 kilograms or more, migrate into these waters for the purpose of spawning, and their subsequent death adds probably in excess of 2,000,000 kilograms of decomposable organic matter to the waters of the Karluk drainage system. The decomposition of this material makes a very important contribution to the quantity of both organic and inorganic substances that are held in solution by these waters.

Some observations made during the summer of 1927 serve to give an idea of the abundance of dead salmon in some of the streams. On July 17, Canyon Creek was listed as having comparatively few dead salmon; on July 21 it was estimated that there were 50,000 to 60,000 dead salmon in the two forks of Upper Thumb River. On July 25 Moraine Creek was listed as having about 10,000 dead fish.

Shostrom, Clough, and Clark (1924) give the following results for chemical analyses of bone-free samples of the red salmon of Karluk River: Moisture, 69.5 per cent; fat, 5.6 per cent; protein, 21.6 per cent; and ash, 1.3 per cent. They state that bone constitutes 2.2 per cent of the total weight of the fish. On this basis more than 400,000 kilograms of the total estimated decomposable matter contributed by the dead salmon would consist of protein material, and the decomposition of this protein furnishes a supply of nitrogen compounds to these stream and lake waters. In their final stages of decomposition these compounds yield ammonia, nitrites and

nitrates which, in turn, serve as a source of nitrogen for the various plant forms that populate these lakes and streams; they are of special importance to the organisms that constitute the phytoplankton.

No data are available for the phosphorus content of the red salmon, but Atwater (1892) states that P_2O_5 constitutes 0.69 per cent of the flesh of the California salmon and Taylor (1926) gives 0.57 per cent for the edible portion of the chinook salmon. From these results the P_2O_5 content of the red salmon may be estimated as about 0.6 per cent, which is equivalent to 0.26 per cent when expressed in terms of the element phosphorus. This percentage represents about 5,000 kilograms of phosphorus in the estimated 2,000,000 kilograms of organic matter in the red salmon which migrate into these waters to spawn in an average year. In the process of decomposition this phosphorus is liberated and becomes available for the plants which thrive in these waters.

Some of the salmon carcasses decompose in very shallow water or are washed up on the shores of the lakes and streams above the water line; in such cases a large part or all of the ammonia nitrogen is lost to the water, but the nitrates and phosphates of those decomposing on shore are washed back into the water by rain or melting snow and thus become available for the aquatic plants. The nitrates and phosphates derived from the decaying salmon are excellent fertilizers and serve to stimulate the growth of phytoplankton organisms. This is shown by the fact that enormous growths of certain algæ are correlated with an abundance of decomposing salmon carcasses in Thumb Lake, and also by the fact that Karluk Lake supports a larger crop of phytoplankton than several lakes belonging to the same class; the latter problem is discussed further in the section dealing with the plankton of Karluk Lake.

The decomposition of the salmon carcasses in the lower courses of the streams accounts for the differences in the quantity of nitrogen and phosphorus found in the upper and lower courses of some of the streams. The samples taken at the upper stations were obtained from portions of the streams that were not occupied by the salmon, consequently the water in these localities contained only the nitrogen and phosphorus compounds leached from the earth through which the water had passed; in the lower courses of the streams, on the other hand, these amounts were augmented by those derived from the decomposing salmon. Some of the streams were not as densely populated by the salmon as others, and this accounts for the differences noted between the different streams.

CHEMISTRY OF BOTTOM DEPOSITS

Five samples of bottom material were collected in Karluk Lake and one each from Thumb and O'Malley Lakes during July and August, 1927, for the purpose of making chemical analyses of them. One of the samples was taken in the deepest part of Karluk Lake, indicated as station 1 on the map, Figure 1. One was taken in the deeper part of The Thumb (station 2 on the map), and two others were secured in this basin of Karluk Lake. One sample was also obtained in the third or lower basin of Karluk Lake which is indicated as station 3 on the map. One sample was taken in the deepest part of Thumb Lake and another from that of O'Malley Lake.

The samples were spread out and air dried as promptly as possible after they were secured. When dry they were placed in glass containers and kept until the analyses were made in the autumn of 1927. The air-dried samples were ground in a disk mill; the material was then spread out on watch glasses and dried in a vacuum desiccator

for 10 days at a temperature of 70° C. The drying was carried out at 70° rather than at 100° or higher in order to avoid the possible loss of carbonaceous material, especially of any volatile oils that might be present. The moisture content ranged from 1.43 to 5.19 per cent of the weight of the undried material in the various samples.

The character of the water in these three lakes is indicated in the analyses given in Tables 8 and 9. There is a comparatively small amount of fixed or bound carbon dioxide present and relatively small amounts of calcium, magnesium, and silica. The water, therefore, may be regarded as having a medium hardness. It might be better, in fact, to class them as soft-water lakes. They are certainly at the lower limit of the class with medium hardness.

The results of the analyses of the bottom deposits are given in Table 11. One of the striking features of these bottom deposits is the large percentage of silica found in them; this substance comprises from 60 per cent to a little more than 73 per cent of the dry material. Such high percentages of silica raised a question regarding its source and portions of the various samples were submitted to Dr. Albert Mann who examined them for diatom remains. He found the shells of 67 different species of diatoms in these bottom deposits. His estimates of the percentages of diatoms in the various samples from Karluk Lake, based upon his microscopical examination, show a rather striking similarity to the results obtained in the chemical analyses. His statement regarding the sample from station 3 of Karluk Lake is "nearly pure diatoms, 80 to 90 per cent of the mass." The 40-meter sample from The Thumb is estimated as 60 per cent or more diatoms, and the 125-meter sample from station 1 of Karluk Lake as 75 to 80 per cent. He states that diatoms are not so abundant in the samples from Thumb and O'Malley Lakes (20 to 30 per cent), but the percentage of silica is the same in them as in those from Karluk Lake. No explanation of this difference is evident from the data in hand. (See Doctor Mann's report on p. 434.)

There is almost a twofold difference in the percentage of iron in the various samples and likewise almost a fourfold difference in the percentage of alumina. The calcium and magnesium content of these bottom deposits is small and the same is true of the phosphorus, sulphate, and carbon dioxide. The percentage of organic carbon shows a little more than a fourfold difference. The largest percentage was found in the sample from O'Malley Lake. Large aquatic plants grow much more abundantly in this lake than in the other two, and it seems probable that they make an important contribution to the bottom deposits here and thus increase the amount of organic carbon therein.

In comparison with the results obtained on other lakes, the high percentage of silica is the outstanding characteristic of the bottom deposits of these three Alaskan lakes. Bottom material from two of the lakes of northeastern Wisconsin yielded a little more than 42 per cent of silica and this is the largest percentage that has been found in any of the Wisconsin lakes up to the present time. A maximum of 54 per cent was found in one sample from Lake Balaton, Hungary (Emszt 1911), and a little over 36 per cent was the largest amount found in the bottom deposits of the lakes at Lunz, Austria (Mulley, 1914). Halbfass (1923) reports a maximum of 78 per cent of silica in Lake Girotte and 74 per cent in Lac Pavin.

The small percentage of calcium is also an important characteristic of the deposits of these Alaskan lakes. Smaller percentages have been obtained only in the very soft water lakes of northeastern Wisconsin. Less than 1 per cent of calcium has been found in 4 of these soft-water lakes, and from 1 to almost 2 per cent in 8

others. In the hard-water lakes of southeastern Wisconsin, the percentage of calcium shows a maximum of a little more than 17 per cent, while a bottom sample from one of the lakes at Lunz, Austria, yielded a little more than 38 per cent of calcium and one from Lake Balaton, Hungary, a little more than 37 per cent.

The percentage of organic carbon is distinctly smaller in the bottom samples from the Alaskan lakes than in those obtained from the lakes of northeastern Wisconsin; in the latter samples the percentage of organic carbon varied from somewhat more than 10 to almost 39 per cent of the dry weight of the deposits.

TABLE 11.—*Chemical analyses of bottom deposits of Alaskan lakes*

[The samples were taken in 1927 with a small Ekman dredge, so that they represent only the upper 15 cm. of the deposits. The results of the analyses are given in percentages of the dry weight of the samples. Upon drying the various samples lost from 1.43 to 5.19 per cent of moisture]

Lake	Date	Depth	SiO_2	Fe_2O_3	Al_2O_3	Ca	Mg	P_2O_5	SO_4	CO_2	Org. C
		Meters									
Karluk, station 1	Aug. 13	125	60.50	4.93	6.88	1.62	0.44	0.92	1.06	0.69	4.58
Karluk, The Thumb	Aug. 8	17	73.07	3.36	5.65	1.86	.54	1.37	1.85	.70	5.34
Do	do	38	63.91	5.45	11.76	2.60	1.50	.65	.44	.52	1.95
Do	do	40	66.10	7.00	12.22	2.05	1.30	.82	.51	.20	4.22
Karluk, station 3	July 19	50	69.81	6.05	5.42	2.96	.90	.92	1.37	.67	5.05
Thumb Lake	July 21	10	60.00	6.42	9.65	1.89	1.07	1.02	1.78	.20	6.56
O'Malley Lake	July 23	12	71.76	4.32	3.75	2.71	.93	1.35	1.12	.80	8.50

PLANKTON DATA

NET PLANKTON

Catches of net plankton were obtained from Karluk, Thumb, and O'Malley Lakes at the same time that samples were taken for the chemical analyses, and at other times also. This plankton material was secured by means of the regular type of closing net that has been used in making catches on the Finger Lakes of New York, on a number of lakes in northwestern United States, and on various lakes in Wisconsin. This type of closing net has been fully described by Juday (1916) so that no further description is necessary at this time. The net has a relatively large straining surface of bolting cloth in proportion to its opening and numerous tests have shown that its coefficient lies between 1.8 and 2; that is, it strains approximately half of the water in the column through which it is hauled.

The plankton material obtained in these catches was enumerated by the usual method and the numbers found in each catch were multiplied by 2 in order to indicate the total number of organisms in the column through which the net passed.

The results of these quantitative studies are given in Table 12 in which the average numbers of organisms per liter of water are indicated for the different series. No attempt was made to count the different species separately; the different forms were enumerated by genera, and the various genera were then combined into groups as shown in the table.

The great variety of organisms found in the catches is shown by the following list of genera which are represented in the material.

Cladocera:
- Alona.
- Bosmina.
- Chydorus.
- Daphnia.
- Holopedium.

Copepoda:
- Cyclops.
- Diaptomus.
- Epischura.

Rotifera:
- Anuraea.

Rotifera—Continued.
- Asplanchna.
- Asplanchnopus.
- Brachionus.
- Conochilus.
- Conochiloides.

Rotifera—Continued.
- Diplois.
- Diurella.
- Floscularia.
- Gastropus.
- Monostyla,

Rotifera—Continued.
- Notholca.
- Ploesoma.
- Polyarthra.
- Rattulus.
- Synchaeta.
- Triarthra.

Protozoa:
- Actinosphaerium.
- Ceratium.
- Dinobryon.
- Epistylis.
- Glenodinium.
- Mallomonas.
- Peridinium.
- Stentor.
- Uroglena.
- Vorticella.

Blue-green algæ:
- Anabaena.
- Aphanocapsa.
- Chroococcus.
- Coelosphaerium.
- Gloeocapsa.
- Leptobasis.
- Lyngbya.
- Microcystis.
- Oscillatoria.
- Spirulina.

Green algæ:
- Ankistrodesmus.
- Actinastrum.
- Botryococcus.
- Coelastrum.
- Chlamydomonas.
- Chlorangium.

Green algæ—Continued.
- Cosmarium.
- Crucigenia.
- Mougeotia.
- Pediastrum.
- Pandorina.
- Staurastrum.
- Scenedesmus.
- Sphaerocystis.
- Spondylosium.
- Tetraspora.
- Ulothrix.

Diatoms:
- Asterionella.
- Amphora.
- Ceratoneis.
- Cocconeis.
- Cyclotella.

Diatoms—Continued.
- Cymbella.
- Epithemia.
- Fragilaria.
- Gomphonema.
- Melosira.
- Navicula.
- Nitzschia.
- Stephanodiscus.
- Synedra.
- Tabellaria.

TABLE 12.—*Numerical analysis of the net plankton catches of Karluk, Thumb, and O'Malley Lakes*

[The average number of organisms per liter of water from surface to bottom is indicated for the different series]

Date	Depth	Cladocera	Copepoda	Nauplii	Rotifera	Protozoa	Blue-green algæ	Green algæ	Diatoms
KARLUK STATION 1									
	Meters								
July 19, 1927	0–125	1.0	8.7	30.5	244.0	11	273	2,928	4,457
July 31, 1927	0–125	1.3	1.9	32.3	257.0	1,279	445	28,561	4,802
Aug. 13, 1927	0–125	.7	4.0	47.0	214.0	543	241	1,547	553
Aug. 24, 1927	0–125	2.5	12.6	53.4	106.0	729	65	3,679	542
Sept. 13, 1927	0–125	2.1	15.3	37.7	29.3	43	9	3,681	226
July 10, 1928	0–125	.8	5.0	32.4	107.0	42	61	2,378	752
Sept. 3, 1928	0–125	8.1	24.5	100.0	54.5	133	18	4,121	417
July 9, 1929	0–125	1.2	8.9	57.5	164.0	204	13	2,645	3,591
Sept. 8, 1929	0–125	6.7	35.5	82.0	70.0	274	191	1,482	1,624
July 12, 1930	0–125	.4	14.7	3.3	159.0	309	868	2,164	7,025
Sept. 9, 1930	0–125	1.5	7.3	26.0	60.7	177	548	634	605
KARLUK STATION 2									
July 21, 1927	0–45	1.8	8.5	9.8	367.0	14	1,058	23,452	67,424
Aug. 2. 1927	0–45	4.0	7.0	52.7	316.0	1,990	260	16,721	10,285
Aug. 12, 1927	0–45	6.2	5.1	28.1	322.0	663	414	2,544	3,596
Aug. 26, 1927	0–45	7.0	17.0	51.0	172.0	629	233	8,399	23,997
Sept. 15, 1927	0–45	.6	6.5	12.5	17.2	43	6	1,298	4,114
July 11, 1928	0–45	.2	2.7	8.9	143.0	154	6	2,853	5,582
Sept. 2, 1928	0–45	13.4	33.0	120.0	90.0	207	59	2,555	1,270
July 13, 1929	0–45	.9	7.0	21.8	148.0	242	78	1,105	3,896
Sept. 7, 1929	0–45	5.8	37.6	106.0	92.0	65	1,473	1,009	8,449
July 13, 1930	0–45	.5	5.2	2.9	204.0	430	40	2,283	50,268
Sept. 2, 1930	0–45	4.4	19.9	181.0	240.0	24	484	2,338	748
KARLUK STATION 3									
July 19, 1927	0–50	0.9	5.5	15.3	361.0	21	760	19,910	28,485
July 9, 1929	0–50	1.0	10.0	20.6	188.0	281	149	1,622	948
Sept. 11, 1929	0–50	7.1	46.9	122.0	130.0	221	352	1,081	1,911
THUMB LAKE									
July 21, 1927	0–10	29.5	29.1	24.1	370.0	-----	-----	3,896	1,375,370
Aug. 3, 1927	0–10	160.0	33.8	4.6	405.0	-----	31,172	-----	985,825
Aug. 12, 1927	0–10	4.2	13.4	.9	58.2	355	-----	-----	889,000
Aug. 26, 1927	0–10	17.8	5.0	.9	133.0	195	-----	-----	55,134
Sept. 16, 1927	0–10	5.0	.9	1.4	456.0	178	-----	355	309,906
July 9, 1928	0–10	2.5	.9	69.0	87.0	433	-----	660	146,286
Sept. 3, 1928	0–10	10.5	5.8	2.2	78.4	949	-----	11,979	104,628
July 11, 1929	0–10	.5	.2	6.0	177.0	6,647	-----	130	322,010
Sept. 7, 1929	0–10	103.0	8.3	6.0	1,433.0	174	71,948	17,302	793,320
July 13, 1930	0–10	31.0	46.2	489.0	1,120.0	157,400	-----	94,724	7,386,500
Sept. 6, 1930	0–10	99.5	12.8	1.6	2,679.0	852	118	5,828	1,752

TABLE 12.—*Numerical analysis of the net plankton catches of Karluk, Thumb, and O'Malley Lakes*—Continued

[The average number of organisms per liter of water from surface to bottom is indicated for the different series]

O'MALLEY LAKE

Date	Depth	Cladocera	Copepoda	Nauplii	Rotifera	Protozoa	Blue-green algæ	Green algæ	Diatoms
	Meters								
July 23, 1927	0–10	1.2	11.8	6.9	386.0		129		36,040
Aug. 10, 1927	0–10	5.0	12.9	5.5	167.0			3,896	502,650
Aug. 24, 1927	0–10	2.7	1.8	8.3	147.0	782	7,820	1,564	133,466
Sept. 14, 1927	0–10	6.0	1.8	1.0	180.0		1,760	782	145,445
July 10, 1929	0–10	11.0	1.8	9.7	364.0	40		1,447	12,104
Sept 12, 1929	0–10	1.2	2.8	4.6	175.0	241	1,564	404	6,737
July 15, 1930	0–10	11.6	6.7	9.7	205.0	227	1,173	1,315	12,789
Sept. 5, 1930	0–10	3.7	3.0	2.8	246.0	178	568	2,523	21,495

KARLUK LAKE

Five series of catches were taken in the deepest part of Karluk Lake (station 1) in 1927 and two series in each of the other years, 1928 to 1930, respectively. Twelve series of catches were also taken at station 2 in the Thumb during this same period of time and two at station 3 in the Lower Basin. (See map, fig. 1.)

Zooplankton.—The Cladocera were represented in Karluk Lake by specimens of Bosmina and Daphnia. Numerically these two forms were about equally abundant in the various catches. Both forms were most abundant in the upper 50 meters; in some series, in fact, they were not found in the catches taken below this depth. The smallest number of Cladocera was noted in the series of catches taken on July 12, 1930. The maximum number of Daphnia was obtained in the 5–10-meter stratum at station 1 on September 8, 1929, namely, nine individuals per liter of water. The largest catch of Bosmina (13 per liter) was found in the 30–50-meter stratum on September 3, 1928. (See Table 12.)

The Copepoda were represented in the catches by species of Diaptomus and Cyclops; individuals belonging to the latter genus were more abundant than those belonging to the former. Both forms were more abundant between the surface and 70 meters than they were below the latter depth. The maximum number of Diaptomus was found in the 0–5-meter catch taken at station 1 on September 8, 1929, namely, 22 individuals per liter of water. In the same catch Cyclops reached the maximum number of 145 per liter. The average number of Copepoda from surface to bottom in the catches taken on September 8, 1929, was 35 per liter. This was the highest average obtained in any of the series at station 1. The copepod nauplii were more numerous than the adults; they were more abundant in the upper 10 to 20 meters than at greater depths. In 1927 the largest average number of nauplii for the entire depth of the lake was found on August 13 when 47 individuals per liter were found. A maximum average of 100 per liter was noted on September 3, 1928. The smallest average number was found on July 12, 1930, namely, 3.3 per liter.

Numerically the Rotifera constituted the major part of the zooplankton in Karluk Lake. Asplanchna, Anuraea, and Polyarthra were the most abundant forms in this group and they were most numerous in the upper 10 meters. Notholca was obtained in considerable numbers below a depth of 15 meters in some of the series. In all of the series the rotifers were much more abundant in July than in September. The decrease in the number of rotifers during the summer is well illustrated in the five

series of catches which were taken at station 1 in 1927. The average number from surface to bottom in the series of catches taken on July 19 was 244 per liter; it was 257 on July 31, then declined to 213 on August 13, fell to 106 on August 24, and reached a minimum of only 30 per liter on September 13. In 1928 the average was 107 per liter on July 10 and 55 on September 3, and similar decreases were noted in the September series taken in 1929 and in 1930.

The protozoan population of Karluk Lake consisted principally of Epistylis and Vorticella. These organisms were attached to the Copepoda; they were found in considerable numbers on both Cyclops and Diaptomus, but they were not present on the Cladocera. A third protozoan, namely, Peridinium, was found in some of the catches taken at station 1. The largest number of protozoa noted at station 1 was obtained in the series taken on July 31, 1927, namely, an average of 1,279 per liter from surface to bottom; at station 2 the largest average number was 1,990 per liter down to a depth of 45 meters, the maximum depth at the station, on August 2, 1927. In the other catches taken at the three stations in Karluk Lake, the average number of protozoa varied from 11 to 729 per liter.

Phytoplankton.—The results obtained in the enumeration of the phytoplankton forms of the net plankton are given in Table 12. This table shows that the blue-green algæ played only a minor rôle in the catches secured between 1927 and 1930, leaving the green algæ and the diatoms as the dominant elements of this group of organisms. As might be expected these forms were most abundant in the upper 20 meters where light conditions were favorable for their photosynthetic activities. The phytoplankton material obtained in the lower strata represented senile or dead individuals that were settling to the bottom, or else organisms that were living saprophytically in this region. A maximum of 102,000 green algæ per liter was found in the 0–10-meter stratum of station 1 on July 31, 1927, and the next largest number was noted in the 15–20 meter catch of this same series. The largest average number of green algæ from surface to bottom was obtained in this series also, namely 28,500 per liter. The diatom maximum at station 1 yielded 25,700 cells and colonies per liter in the 10–15 meter stratum on July 31, 1927; the average number of diatoms from surface to bottom on this date was 4,800 per liter. An average of 7,000 was obtained on July 12, 1930.

The September catches in general showed a smaller number of green algæ and of diatoms than the July catches. The average number of green algæ declined from 28,500 per liter on July 31 to 3,680 on September 13, 1927. Decreases were noted also in 1929 and 1930, but in 1928 the September average was larger than that obtained in July. The diatoms, on the other hand, showed a smaller average number in September than in July from 1927 to 1930, inclusive.

The vertical distribution of various net plankton organisms at station 1 is shown graphically in Figures 3 to 6. The number of individuals belonging to the different forms varies so widely that it is necessary to use the spherical type of curve in order to get all of the groups on the same diagram. The construction of this type of curve has been discussed by Birge and Juday (1922), so that it need not be repeated here. For the purpose of bringing out more clearly the vertical distribution of the Cladocera and Copepoda, the diagrams have been platted on the basis of the number of organisms per cubic meter of water instead of on the liter basis as given in the tables. The blue-green algæ were omitted in some of the diagrams because they were present in such small numbers; for the same reason the Cladocera were omitted in Figure 5.

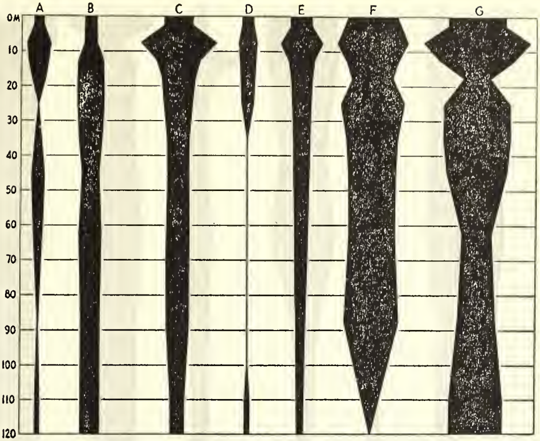

FIGURE 3.—Vertical distribution of net plankton in Karluk Lake, station 1, July 9, 1929. *A*, Diaptomus; *B*, Cyclops; *C*, nauplii; *D*, Cladocera; *E*, Rotifera; *F*, green algæ; *G*, diatoms

These diagrams show that Diaptomus, nauplii and Cladocera were most abundant in the upper 40 to 50 meters of water; Cyclops was more uniformly distributed from surface to bottom, but Figure 6 shows a more marked difference between the upper and lower strata than the other three figures. A relatively small number of nauplii are shown in Figure 5 and they are rather evenly distributed from surface to bottom; larger numbers are represented in Figures 3, 4, and 6, and they are more abundant in the upper strata in these cases. The Rotifera have been omitted from Figure 4 and they are represented only by a comparatively small number in Figure 3; they are present in considerable numbers in Figures 5 and 6, the largest numbers being found in the upper strata.

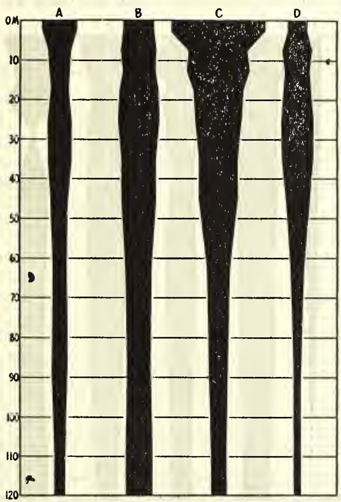

FIGURE 4.—Vertical distribution of zooplankton in Karluk Lake, station 1, September 8, 1929. *A*, Diaptomus; *B*, Cyclops; *C*, nauplii; *D*, Cladocera. Note the large number of nauplii in the upper stratum

Figures 3, 5, and 6 bring out clearly the fact that the algæ were most abundant in the upper 20 meters, but there were large numbers of green algæ and diatoms below this depth as shown in Figures 3 and 5. Attention may be called to the maximum of blue-green algæ in the 10–20-meter stratum in Figure 5 and to the marked decline in the number of green algæ in the 5–10-meter stratum in Figure 5; similar decreases are shown for the diatoms in the 15–20-meter stratum of Figure 3 and in the 10–15-meter stratum of Figure 5.

For purposes of comparison with the results obtained at station 1 several vertical series of catches were taken at station 2 located in The Thumb Basin which has a maximum depth of 46 meters; the series

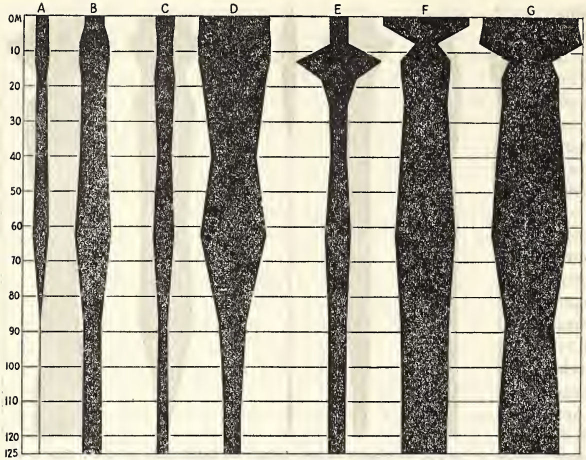

FIGURE 5.—Vertical distribution of the net plankton in Karluk Lake, station 1, July 12, 1930. *A*, Diaptomus; *B*, Cyclops; *C*, nauplii; *D*, Rotifera; *E*, blue-green algæ; *F*, green algæ; *G*, diatoms. The number of Cladocera was too small to be indicated in the diagram

taken at this station extended to a depth of 45 meters. (See fig. 1.) In general, the average number of organisms obtained at these two stations was within the range of variation of duplicate samples taken at a single station. A twofold or threefold variation in number may be expected in certain forms in duplicate catches, and most of the forms in the various series taken at these two stations fall within this range.

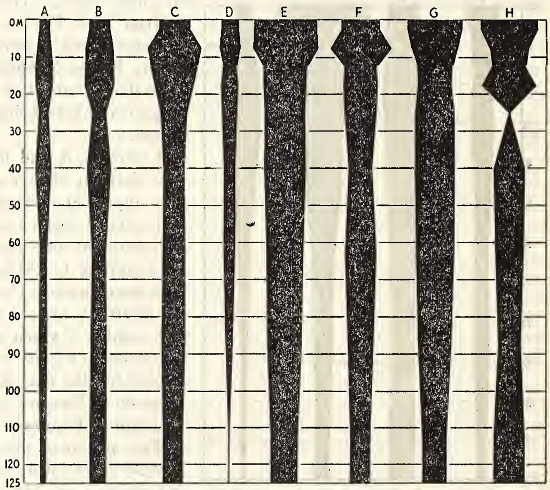

FIGURE 6.—Vertical distribution of the net plankton in Karluk Lake, station 1, September 9, 1930. *A*, Diaptomus; *B*, Cyclops; *C*, nauplii; *D*, Cladocera; *E*, Rotifera; *F*, blue-green algæ; *G*, green algæ; *H*, diatoms

At station 1 on July 19, 1927, the average number of Copepoda in the upper 50 meters was 13 per liter and 5.5 per liter down to 45 meters at station 2; for the same strata the nauplii averaged 19 per liter at station 1 and 15 per liter at station 2, while the Rotifera averaged 350 at station 1 and 360 at station 2. There was an eightfold difference in favor of station 2 in the green algæ and a fivefold dif-

ference in the diatoms. On July 12 and 13, 1928, the average numbers down to 50 and 45 meters, respectively, were substantially the same at station 1 and at station 2 for the green algæ and the rotifers, but the diatoms were about five times as abundant at the latter as at the former station. The nauplii were a little more than five times as abundant at station 1 as at station 2. On July 12 and 13, 1930, there was substantially the same average number of rotifers, nauplii, green algæ and diatoms in the upper 50 meters at station 1 as in the 45-meter series at station 2.

Similar variations in numbers were noted between the catches taken at station 1 and those at station 3. On July 19, 1927, the average number of nauplii down to 50 meters at station 1 was 44 per liter and 19 per liter at station 3; the rotifers numbered 350 per liter at station 1 and 360 at station 3. The green algæ were five times and the diatoms four times as numerous at station 3 as at station 1. On July 9, 1929, the catches in the upper 50 meters at station 1 yielded a larger number of net plankton organisms than those at station 3; the difference was less than twofold in the rotifers and the green algæ, but it was fourfold in the nauplii and fivefold in the diatoms. In the series taken at station 1 on September 9, 1929, and that at station 3 on September 11, 1929, the average number of nauplii, rotifers, and diatoms was somewhat smaller down to a depth of 50 meters in the former than in the latter series, but the reverse was true of the green algæ. A comparison of the average numbers in the series taken at station 2 on July 21, 1927, and on July 13 and September 7, 1929, with those from station 3 on July 19, 1927, and on July 9 and September 11, 1929, shows that the most marked differences are represented in the diatoms; even the maximum difference in this group is only a fourfold one.

THUMB LAKE

Five sets of net catches were secured from Thumb Lake in 1927 and two in each of the other three years, making a total of 11 series. (See Table 12.) The Cladocera were more abundant in Thumb Lake than in the upper 10 meters of Karluk Lake. A maximum of 263 Bosmina per liter was noted in the upper 5 meters of Thumb Lake on August 12, 1927; this form seems to have been concentrated in the upper stratum at this time, since the 5–10-meter stratum showed only 6.5 individuals per liter. On the other hand, a larger number was found in the 5–10-meter stratum (121 individuals per liter) than in the upper 5 meters (82 per liter) on September 7, 1929. Again on September 6, 1930, a larger number of Bosmina was found in the upper 5 meters than in the 5–10-meter stratum. The maximum number of Daphnia (10 per liter) was obtained in the upper 5 meters on August 26, 1927.

A maximum of 92 Cyclops per liter was noted in the 5–8-meter stratum on July 13, 1930. Relatively small numbers of Diaptomus were obtained in Thumb Lake; the maximum was 3 per liter in the upper 3 meters on September 3, 1928. An unusually large number of nauplii was noted in the 5–8 meter stratum on July 13, 1930, namely 968 per liter; the next highest was 202 per liter on July 9, 1928.

The zooplankton of Thumb Lake was characterized by the large number of rotifers. The maximum was found on September 6, 1930, when the average from surface to 8 meters was more than 3,600 per liter. The smallest number of rotifers was obtained in the catches of 1928; on July 9 the average number was 87 per liter and on September 3 it was 78.

Protozoa were most abundant in Thumb Lake on July 13, 1930, when the average number was 157,400 per liter of water.

The phytoplankton consisted chiefly of diatoms; an average of 7,386,000 diatoms per liter was obtained in the net catch taken on July 13, 1930. A maximum average of 94,700 green algæ per liter of water was noted on the same date. The largest number of blue-green algæ was found on September 7, 1929, namely, an average of 71,900 per liter.

O'MALLEY LAKE

Eight series of net catches were taken on O'Malley Lake, four in 1927, and two each in 1929 and 1930. (See Table 12.) In general, the crustacea were not as abundant as in the Thumb Lake catches. The Cladocera were represented by a few Chydorus in one catch and by varying numbers of Bosmina in all of the catches. A maximum of 17 Bosmina per liter was taken in the 5–10 meter catch on July 10, 1929. The Copepoda were represented by a maximum of 8 Diaptomus per liter in one catch and a maximum of 4 Cyclops per liter in another. Epischura appeared in three catches, with a maximum of 5 per liter in one.

As in Karluk and Thumb Lakes, the Rotifera were the dominant group numerically in the zooplankton of O'Malley Lake. The catch taken on July 23, 1927, yielded the largest average number of rotifers, namely, 386 per liter.

Protozoa and blue-green algæ were found in relatively small numbers. The green algæ reached a maximum average of almost 3,900 per liter on August 10, 1927. As in Thumb Lake, the phytoplankton of O'Malley Lake was dominated by the diatoms, but they were not as abundant in the latter as in the former lake; a maximum of 562,600 diatoms per liter was obtained on August 10, 1927.

TABLE 13.—*Average number of net plankton organisms per liter of water in seven American lakes*

Lake	Date	Depth	Cladocera	Copepoda	Nauplii	Rotifera	Protozoa	Blue-green algæ	Green algæ	Diatoms
		Meters								
Canandaigua, N. Y.	Aug. 20, 1910	0–80	1.9	5.4	3.0	0.7	12	39	1	15
Do	July 27, 1918	0–72	.5	1.8	2.4	.7	10	5	2	17
Cayuga, N. Y.	Aug. 12, 1910	0–120	19.2	2.8	10.6	59.0	851	22	----------	3,068
Do	July 30, 1918	0–100	5.0	3.1	2.2	30.0	83	3	----------	19
Seneca, N. Y.	Aug. 4, 1910	0–165	6.3	9.8	16.2	13.2	23	9	----------	230
Do	Aug. 1, 1918	0–170	4.1	9.2	8.7	3.4	19	1	----------	113
Skaneateles, N. Y.	Aug. 15, 1910	0–80	.3	.4	2.5	1.3	92	31	----------	1,384
Crescent, Wash	Aug. 17, 1913	0–160	.01	.8	.2	2.8	2	3	110	----------
Fallen Leaf, Calif	July 25, 1913	0–110	.5	2.1	1.0	4.8	18	----------	----------	282
Karluk	July 9, 1929	0–125	1.2	8.9	57.5	173.8	125	13	2,111	3,592
Do	July 12, 1930	0–125	.4	14.7	3.3	160.0	307	886	2,164	4,638
Do	Sept. 9, 1930	0–125	1.5	8.1	26.0	61.0	18	537	636	605

COMPARISON OF KARLUK WITH OTHER LAKES

Table 13 shows the average number of net plankton organisms per liter of water from surface to bottom in some lakes that are similar to Karluk Lake in depth and character. Four of the Finger Lakes of New York and one each from the States of California and Washington are included in this table. The series of catches represented in these averages were taken with the same type and with the same size of plankton net, so that the general results obtained in the various lakes are comparable.

The average number of Cladocera was larger in Cayuga and Seneca Lakes than in Karluk; they were about the same in Canandaigua and Karluk Lakes, but a smaller average was found in the other three lakes shown in the table. The average number of Copepoda and nauplii was larger in Karluk than in the other six lakes and the same was true of the Rotifera. The average number of protozoa in Cayuga Lake exceeded

that of Karluk Lake, but the average number of the other five lakes was smaller than that of Karluk.

The blue-green and the green algæ were more abundant in Karluk Lake than in the other six lakes. With the exception of the series of net catches taken on Cayuga Lake on August 12, 1910, the average number of diatoms was considerably larger in Karluk Lake than in the other six lakes included in the table. The general results given in this table indicate that the net plankton is more abundant in Karluk than in the other lakes; the most striking difference is the great abundance of green algæ in the former as compared with that group of phytoplankton organisms in the latter.

This greater production of plankton in Karluk Lake is due, in part at least, to the nitrogen and phosphorus compounds that are contributed to the water of this lake and to that of the streams flowing into it by the decomposing carcasses of the red salmon which spawn in its watershed. Both of these substances are essential food materials for the phytoplankton and they serve the function of fertilizers; thus the addition of these compounds derived from the dead salmon to those already present in the water makes it possible for the lake to support a larger crop of phytoplankton. A more abundant crop of phytoplankton will, in turn, support a larger crop of zooplankton forms which depend upon the algæ for food; as a result this abundant supply of phytoplankton and zooplankton provides a good supply of food for the young red salmon, since they feed almost exclusively on plankton material while they inhabit the lake. Thus the fertilizers derived from the adult salmon are very important factors in producing an abundant food supply for the young red salmon. Gilbert and Rich (1927) state that the Karluk fingerling red salmon are unusually large and form a sturdy stock; these authors attribute the large size to the very favorable conditions for growth which they find in this watershed. It seems probable from the results obtained in the present investigation that the chief factor in these favorable growth conditions is the abundant crop of plankton which is available for them in Karluk Lake.

CENTRIFUGE PLANKTON

A series of centrifuge catches was taken at station 2 in Karluk Lake on August 8, 1927, and two sets of these samples were obtained from Thumb Lake, one on August 3 and another on August 12, 1927. These centrifuge catches were taken for the purpose of comparing the number organisms obtained by this method with that obtained with the net; many plankton organisms are so small that they readily pass through the meshes of the net and are thus lost in such a catch. A hand centrifuge operated at a speed of about 1,200 revolutions per minute was used for the centrifuge catches; from 100 cubic centimeters to 120 cubic centimeters of water were used for each catch. Numerical results for the various catches are given in Table 14. The protozoa and blue-green algæ have been omitted from the table because they were found in only 2 of the 11 catches.

The six centrifuge samples taken at station 2 in Karluk Lake on August 8, 1927, yielded an average of 65,600 green algæ and 88,200 diatoms per liter of water. No net catches were taken at station 2 on this date, but a series obtained there on August 12 gave an average of 2,500 green algæ and 3,600 diatoms per liter. The centrifuge material yielded a little more than 25 times as many green algæ and almost 25 times as many diatoms as the net samples obtained on the latter date. The series of net catches taken at station 2 on August 2, 1927, yielded an average of 16,700 green algæ and 10,300 diatoms per liter, so that the centrifuge catches contained only about four times as many green algæ as these net catches and only a little more than eight times as many diatoms.

TABLE 14.—*Number of phytoplankton organisms per liter of water at various depths in hand centrifuge catches taken in Karluk Lake, station 2, and in Thumb Lake in 1927*

Organisms	Karluk Lake, Aug. 8						Thumb Lake				
							Aug. 3		Aug. 12		
	0	5	10	15	25	40	0	10	0	5	10
	Meters	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*	*Meters*
Green algæ:											
Ankistrodesmus										70, 560	
Chlamydomonas	70, 560	211, 685		23, 520	70, 560		70, 560	70, 560	211, 685	105, 843	70, 560
Staurastrum		17, 640									
Scenedesmus									105, 825		
Diatoms:											
Asterionella								141, 123	23, 520		211, 685
Amphora			17, 640								23, 520
Cyclotella			23, 520	70, 560		70, 560					
Fragilaria			70, 560				141, 123	141, 123			
Melosira	70, 560	23, 520	23, 520	35, 280			776, 178	987, 863	917, 300	917, 300	70, 560
Navicula								35, 280			
Synedra		35, 280	17, 640		70, 560		35, 280	423, 370	94, 082	70, 560	35, 280
Stephanodiscus				70, 560							
Tabellaria								70, 560			

The net catches taken in Thumb Lake on August 3, 1927, contained no green algæ, but the diatoms numbered 985,000 per liter of water. The surface and bottom centrifuge catches taken on this date gave an average of 70,500 green algæ and 1,377,000 diatoms per liter; the diatoms, therefore, were less than twice as numerous in the centrifuge catches as in the net material. In the net and centrifuge catches taken in Thumb Lake on August 12, 1927, the average number of diatoms in the former was 889,000 per liter and in the latter 788,000 per liter; in this case the net catches yielded a larger number of diatoms than the centrifuge samples.

Net and centrifuge samples taken in Lake Mendota at Madison, Wis., over a period of two and a half years showed that the latter yielded on the average about five times as much dry organic matter as the former; at certain times the organic matter in the centrifuge plankton was about the same in quantity as that in the net plankton, but at other times it amounted to about twenty-five times as much as that in the net plankton.

SUMMARY

1. The area, maximum and mean depth, volume, temperature, and heat budget of Karluk Lake are given.

2. The chemical results show that the surface water was alkaline (pH 8.6) and that at 125 meters was neutral (pH 7); the water contained an abundance of dissolved oxygen at all depths during the summer, hence it belongs to the oligotrophic type of lakes; the water contained only 9 to 10 milligrams of fixed or bound carbon dioxide per liter.

3. The soluble phosphorus in Karluk Lake varied from 0.002 milligram in the surface water to 0.018 milligram per liter in the lower water; the organic phosphorus ranged from 0.003 to 0.028 milligram per liter in the surface water and from 0.012 to 0.014 milligram per liter in the lower water.

4. The titratable silica ranged from 0 to 0.6 milligram per liter.

5. Very little ammonia nitrogen was found in the surface water of Karluk Lake, but 0.12 milligram per liter was present in the bottom sample from station 2. Practically no nitrite nitrogen was present. The nitrate nitrogen ranged from 0.012 milligram in the surface water to 0.052 milligram per liter in the bottom water.

6. The water yielded from 5 milligrams to a little more than 6 milligrams of calcium per liter and from a little more than 3 to almost 6 milligrams of magnesium per liter.

7. The bottom deposits contained from 60 to 73 per cent of silica with only small percentages of calcium and magnesium.

8. The quantity of phosphorus, silica, and nitrogen was somewhat larger in Thumb and O'Malley Lakes than in Karluk Lake.

9. Larger amounts of carbon dioxide, silica, ammonia, and nitrate nitrogen were found in some of the affluents than in the surface water of Karluk Lake.

10. The decomposition of the dead salmon affects the chemical status of the water in the three lakes and their affluents.

11. The net zooplankton of Karluk Lake was character zed by a large population of Rotifera.

12. The phytoplankton of this lake consisted chiefly of green algæ and diatoms. These two forms were more abundant in July than in September.

13. In general, the net plankton was more abundant in Karluk Lake than in four of the Finger Lakes of New York and in two of the western lakes.

14 The net zooplankton of Thumb Lake was more abundant than that of the upper 10 meters of Karluk Lake. The same was true of the phytoplankton.

15. In general, the net plankton was not as abundant in O'Malley Lake as in Thumb Lake.

16. The rich crop of plankton produced by these lakes is due, in part at least, to fertilizing substances contributed to their waters by the decomposing carcasses of the salmon.

17. The large crop of plankton furnishes an abundant supply of food for the young salmon and, as a result, the fingerling salmon of Karluk Lake are unusually large and sturdy.

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Part II. DIATOMS OF THE BOTTOM DEPOSITS OF KARLUK LAKE

By Albert Mann

During the course of certain investigations relating to the red salmon of Karluk River, Kodiak Island, Alaska, the investigators of the United States Bureau of Fisheries have secured limnological data in Karluk Lake and the two smaller lakes, Thumb and O'Malley, which are tributary to the main lake. These lakes have been surveyed and described by Gilbert and Rich (1927). In 1927 samples of the bottom deposits were secured by means of an Ekman dredge. A chemical analysis showed an unusually high silicon content in the deposits of each of these lakes (Black, 1929). It seemed probable that this was due to an abundance of diatoms and eight samples were submitted to the writer for study. All are high in diatom content, some of them remarkably so, from 80 to 90 per cent, which accounts for the high silicon content. The great richness and nutritive value of this bottom material is worthy of note.

The data bearing on the samples and remarks on the general character of their composition are given below:

1. *Lower basin, Karluk Lake (station 3) 50 meters, July 19, 1927.*—Nearly pure diatoms, 80 to 90 per cent of the mass. Mostly two species, *Cyclotella Bodanica* and *Stephanodiscus Niagarae*, the former outnumbering the latter 3 to 1. Scanty representatives of *Cymbella Mexicana* var. *Kamtschatica*, *Gomphonema herculeanum*, *Epithemia Zebra*, *Navicula tenella*, *Melosira Italica*, *Amphora ovalis*, *Surirella robusta*, etc.

2. *Thumb Lake, 10 meters, July 21, 1927.*—80 to 90 per cent diatoms; as in the last, mostly *Cyclotella Bodanica* and *Stephanodiscus Niagarae* in ratio of 3 to 1. Also

Cymbella Mexicana var. *Kamtschatica, Cymbella ventricosa, Melosira crenulata, Navicula elliptica, Gomphonema subclavatum, Tabellaria flocculosa,* etc.

3. *O'Malley Lake, 12 meters, July 23, 1927.*—Diatoms fewer, 20 to 30 per cent of the mass. Much fine quartz sand and decayed plant tissue. Here *Cyclotella Bodanica* and *Stephanodiscus Niagarae,* although present, are few; *Surirella elegans* is frequent, but the bulk of the diatoms is made up of minute species—*Tabellaria flocculosa, Melosira crenulata* var. *tenuis, Fragilaria construens, Ceratoneis arcus, Cymbella cistula,* etc.

4. *O'Malley Lake, July 23, 1927.*—The exact locality where this sample was taken was not recorded, but it was in comparatively shallow water, not over 2 meters, and probably near the head of the lake where the bottom consists largely of rather fine dark sand. Over half the mass is decayed plant tissue, mixed with sand. *Cyclotella Bodanica,* generally prolific in the other samples, seems to be wanting here, and *Stephanodiscus Niagarae* is scanty. Among the relatively few diatoms the following were prominent: *Melosira crenulata* var. *tenuis, Navicula elliptica, Navicula viridis, Epithemia Zebra, Cymbella ventricosa, Fragilaria construens, Tabellaria flocculosa,* etc.

5. *The Thumb, Karluk Lake (station 2) 40 meters, August 8, 1927.*—Sixty per cent or more is diatoms, the rest decayed plant tissue and a mere trace of sand. *Cyclotella Bodanica* and *Stephanodiscus Niagarae* compose four-fifths of the diatom bulk. Also present were *Cymbella Ehrenbergii, Cymbella gastroides, Cymbella cistula, Cymbella Helvetica, Navicula lata, Navicula major, Navicula viridis,* etc.

6. *The Thumb, Karluk Lake, 38 meters, August 8, 1927.*—Diatoms 30 to 40 per cent of the mass. Much sand and coarse plant tissue, moss and wood fiber. *Cyclotella Bodanica* and *Stephanodiscus Niagarae* dominant, about 3 to 1. Also *Cymbella Mexicana* var. *Kamtschatica, Epithemia turgida, Surirella biseriata, Surirella elegans, Melosira arenaria, Melosira Italica, Fragilaria construens* and desmids (Micrasterias).

7. *The Thumb, Karluk Lake, 17 meters, August 8, 1927.*—Not over 20 per cent diatoms, mostly decayed plant tissue and a little sand. *Cyclotella Bodanica* and *Stephanodiscus Niagarae* are here in abeyance; large chains of *Melosira arenaria* are frequent, also *Amphora Lybica, Amphora ovalis, Navicula elliptica, Gomphonema geminatum, Cymbella Helvetica, Pleurosigma acuminatum.* Some desmids (*Staurastrum gracile*) and some pin-head sponge spicules.

8. *Karluk Lake, upper basin (station 1) 125 meters, August 13, 1927.*—Seventy-five to eighty per cent of the mass is diatoms and of these four-fifths are *Cyclotella Bodanica* and *Stephanodiscus Niagarae* in their usual ratio of 3 to 1. The remainder is decayed plant tissue with practically no sand or spicules. Other diatoms are *Cymbella gastroides, Cymbella cistula, Rhoicosphenia curvata,* etc.

It is noticeable that the greatest abundance of diatoms in the deposits is found in the main basins of Karluk Lake and in Thumb Lake. The bottom of O'Malley Lake, even in the center of its basin (sample 3) is much less rich than are the samples from the other two lakes. The three samples from The Thumb are interesting in that they show a distinct negative correlation between the proportion of diatoms in the deposits and the depth from which they came. The Thumb is really a large, well-marked bay containing one of the main basins of Karluk Lake. The largest stream tributary to Karluk Lake, Thumb River, enters at the head of The Thumb and during and subsequent to the spawning season carries into the lake large quantities of organic matter derived from the decaying bodies of the spawned out salmon. In making the collections of bottom samples an attempt was made to get a series from about the center of the basin up toward the mouth of Thumb River. The first sample of

this series was taken in about 40 meters, near the center of the basin and approximately one-half mile from the mouth of the river. The second sample was taken about one-fourth mile from the mouth of the river in 38 meters, and an attempt was then made to get a sample from a point approximately 100 yards from the mouth of the river in about 20 meters. This last was not successful, however, on account of twigs and other débris which prevented the dredge from closing. After several trials the attempt was abandoned and a sample taken in 17 meters near what is known as Island Point on the western side of Thumb Bay and about three-fourths mile from the mouth of the river.

Following is a list of the species of diatoms found in the collections as a whole:

Amphipleura pellucida K.
Amphora Lybica E.
Amphora ovalis K.
Ceratoneis arcus K.
Cocconeis Placentula E.
Cyclotella Bodanica Eul.
Cyclotella antiqua W. S.
Cymatopleura Solea (Breb.) W. S.
Cymbella cæspitosa (K.) Cl.
Cymbella cistula (Hemp.) Kirch.
Cymbella cuspidata K.
Cymbella Ehrenbergii K.
Cymbella gastroides K.
Cymbella Helvetica K. (not W. S.)
Cymbella Mexicana var. *Kamtschatica* Grun.
Cymbella ventricosa K. (not Ag.)
Denticula tenuis K., var.
Diatoma anceps (E.) Grun.
Epithemia turgida (E.) K.
Epithemia Zebra (E.) K.
Eunotia bidens (E.) W. S.
Eunotia lunaris (E.) Grun.
Eunotia prærupta E.
Fragilaria construens (E.) Grun.
Fragilaria Harrisonii (W. S.) Grun.
Frustulia rhomboides (E.) De T.
Gomphonema constrictum E. and varieties.
Gomphonema geminatum (Lyng.) Ag.
Gomphonema herculeanum E.
Gomphonema subclavatum Grun.
Hantzschia amphioxys (E.) Grun.
Melosira arenaria Moore.
Melosira crenulata var. *tenuis* (K.) Grun.
Melosira Italica (E). K.
Melosira Rœsæna Rab.
Melosira varians Ag.
Meridion circulare Ag.
Navicula amphirhynchus E.
Navicula borealis (E.) K.
Navicula commutata Grun.
Navicula elliptica K.
Navicula Gastrum (E.) Donk.
Navicula Iridis var. *dilatata* (E.)
Navicula lata W. S.
Navicula limosa K.
Navicula major (K.) Grun., char. emend.
Navicula mesolepta E.
Navicula Placentula (E.) K.
Navicula rupestris (Hantz.) A. S.
Navicula tenella Breb.
Navicula transversa A. S.
Navicula viridis (W. S.) A. S., char. amend.
Nitzschia Brebissonii W. S.
Nitzschia palea (K.) W. S.
Pleurosigma acuminatum (K.) Grun.
Rhoicosphenia curvata Grun.
Rhopalodia gibba (E.) Muell.
Stauroneis Phoenicenteron E., and varieties.
Stephanodiscus Niagaræ E.
Surirella amphioxys W. S.
Surirella bifrons E.
Surirella biseriata (E.) Breb.
Surirella elegans E.
Surirella robusta E.
Synedra delicatissima W. S.
Synedra subæqualis Grun.
Tabellaria flocculosa (Roth) K.

The scarcity of members of the genus Pleurosigma in all the samples is noteworthy; for it is a semisaprophytic genus and the unusually high percentage of decaying organic matter in all of the gatherings would presuppose an abundance of Pleurosigma. A possible explanation of this scantiness is that the genus as a whole thrives best in temperate and subtropical waters.

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1927. Investigations concerning red-salmon runs to the Karluk River, Alaska. Bulletin, United States Bureau of Fisheries, Vol. XLIII, Part II, 1927 (1929), pp. 1–69, 34 figs. Washington.

STATISTICAL REVIEW OF THE ALASKA SALMON FISHERIES PART IV: SOUTHEASTERN ALASKA[1]

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CONTENTS

INTRODUCTION

This review deals with the salmon fisheries of southeastern Alaska in the same way that those of central and western Alaska were treated in parts I, II, and III.[2] It covers statistically the history of these fisheries from the inception of the salmon industry in 1878 to the end of 1927, a period of 50 years. Data for the 26 years prior to 1904 were obtained from reports by Moser[3] and agents of the Treasury Department,[4] which then had supervision of these fisheries; for the remaining 24 years they were taken from formal statements of the operators now filed in the office of the Bureau of Fisheries at Washington.

For the purpose of this review southeastern Alaska has been divided into 17 districts, relatively distinct geographically and often with individual peculiarities such as seasonal variations in the appearance of the runs, the methods of fishing, the migration routes of the incoming salmon, the relative abundance of the several species,

[1] Approved for publication, Dec. 1, 1932.

[2] Statistical Review of the Alaska Salmon Fisheries. Pt. I: Bristol Bay and the Alaska Peninsula. By Willis H. Rich and Edward M. Ball. Bulletin, U.S. Bureau of Fisheries, vol. XLIV, 1928 (1929), pp. 41-95, 20 figs. Washington.

Ibid.—Pt. II: Chignik to Resurrection Bay. Bulletin, U.S. Bureau of Fisheries, vol. XLVI, 1930 (1931), pp. 643-712, 11 figs. Washington.

Ibid.—Pt. III: Prince William Sound, Copper River, and Bering River. Bulletin, U.S. Bureau of Fisheries, vol. XLVII, 1931, pp. 187-247, 10 figs. Washington.

[3] The Salmon and Salmon Fisheries of Alaska. By Jefferson F. Moser. Bulletin, U.S. Fish Commission, vol. XVIII, 1898 (1899), pp. 1-178. Washington.

Alaska Salmon Investigations in 1900 and 1901. By Jefferson F. Moser. Bulletin, U.S. Fish Commission, vol. XXI, 1901 (1902), pp. 173-398. Washington.

[4] The reports of the agents of the Treasury Department on the salmon fisheries of Alaska covered the period 1892 to 1904 (except 1893) and appeared as Treasury Department, Senate and House documents. The authors were: 1892, Max Pracht; 1894 and 1895, Joseph Murray; 1896, G. R. Tingle; and 1897 to 1904, H. M. Kutchin.

etc. These districts are listed in the table of contents and a map of each is given in the text with the corresponding discussion.

The nature and imperfections of the data with which we are dealing have been mentioned repeatedly in the preceding reports of this series, but the difficulties encountered in the collection and handling of data from other parts of Alaska have been multiplied manyfold in the present study. This is due primarily to the lack of clear distinction between the catches in different sections, in other words, to the fact that the geographical regions (which were the only sort of regions that could be set up) do not and cannot be made to conform to the biological conditions. It is probable that no district in southeastern Alaska, excepting possibly Yakutat, draws its quota of salmon from a single stream or even from a group of streams that can be set down definitely. This is perhaps particularly true of the pinks, chums, and cohos, although it applies more or less to the reds and kings as well. In addition to this difficulty southeastern Alaska is such a large district that confusion in records and the indefiniteness of allocation to the localities in which the fish were caught has been tremendously increased. Thus it has frequently happened that two or more major localities in separate districts were linked together in reporting the catch, making accurate allocation of catches to specific waters wholly impossible. Faulty terminology, confusion of names and the interchange of fish by sale and resale added to the complications. Furthermore the general failure of independent seiners, gill netters, trollers, and trap operators to file reports of their catches in several years increased the difficulties of assembling the data by districts. In several instances coho- and king-salmon catches were reported in pounds instead of fish, thus necessitating estimates of the number of fish handled before such data could be used. Records were often incomplete, resulting in many unallocated catches which, in some instances, aggregated a large proportion of the total catch. And in many cases the catches could not be allocated even to one of the major districts, but had to be set out in a separate table as the unallocated catch of southeastern Alaska. Data are also presented in separate tables, or as a section of the main table for each district, showing the number of coho and king salmon taken by trollers. In a few cases, where the catches were insignificant, this information was given in a footnote below the respective tables.

Records for the earlier years of fishing throughout southeastern Alaska give no reliable indication of the abundance of salmon at any time. Canneries were few, comparatively small, and without the equipment for the rapid handling of fish that is now used in all modern plants; fishing appliances were less effective in the more open waters of the district than they are today, and in consequence a much smaller percentage of the runs was taken. The fluctuations in catches in these earlier years, except of reds, was due to the limited market for the cheaper grades of fish, as cannery men were not inclined to pack more than they could sell. This applied to both pinks and chums. Cohos were also affected in that frequently capacity packs of other species were made by some canneries before the cohos came and therefore no efforts were made to take that species. Changes in laws and regulations affected the catches of all species especially after 1923. All of these factors must be considered in the analysis of the catch data for all major districts in southeastern Alaska, if anything like a true understanding of the fluctuations in reported catches is to be reached.

The tables show in addition to catches the number of fishing appliances used in each district. These data also are unsatisfactory, but it is believed that, in general, they are not far from the truth. The following general principles were applied in

allocating gear whenever the records were not clear. In determining the number of seines in operation at least one seine was counted for each locality fished by an operator regardless of the number reported by him, and, if the catch was large in a given locality, the number of seines was increased correspondingly on the basis of an average catch of approximately 20,000 fish per seine. For example, if a company reported using 5 seines and took salmon from 10 localities, it was assumed that the equivalent of 10 seines had been used, the object being to show the number of seines required to make the stated catches if all the localities from which salmon were taken had been fished simultaneously by the fishermen resorting thereto. This procedure was not necessary in respect to traps, as they are fixed appliances. So-called "dummy" traps were not counted. The number of gill nets is believed to agree with the number reported by the operators, which is admittedly incomplete, as no record was available showing the number of nets used by independent fishermen operating their own gear. Likewise no attempt was made to show the number of lines used by trollers, as this class of fishermen consistently failed to submit reports covering their operations.

If the figures presented in this report are compared with those previously published either by the Bureau of Fisheries or by other agencies it will be found that they seldom agree exactly and are sometimes at rather wide variance. Considerable time has been spent in an attempt to reconcile these data with, at least, those previously reported by the Bureau of Fisheries, but without conspicuous success. The causes of these differences are many; but the chief one is the fact that in all such compilations, particularly as regards the older records, estimations and arbitrary allocations have been necessary and these have naturally varied even when made by the same person on the same data but at different times several years apart. Some of the earlier figures published in the administrative reports of the Alaska Division [5] contained estimates based on customhouse records which have not been considered in these more recent tabulations. Various situations arise in which personal judgment must be used in determining how the data are to be handled—as, for example, in cases in which packers failed to indicate whether the fish they sold to other operators were included or excluded from the reported catch, and a corresponding failure on the part of the purchasers. Unfortunately the basis of such judgments were never made a part of the records. In a comparatively few cases the discrepancies have been traced to simple errors, typographical and other. There seems to be no good reason for assuming that the previously published data are any more reliable than those contained in the present compilation—in fact, in some cases additional data have come in since the earlier tabulations which appear to make the present data the more reliable. All in all it seems probable that these and the previous records can never be made to agree other than by arbitrarily changing the present figures to correspond with the earlier ones; and in view of all the circumstances this seems unwarranted and unnecessary, and in no way likely to improve our conception of the general situation in the salmon fishery of southeastern Alaska.

[5] These reports comprise an unbroken series, continuing the reports of the agents of the Treasury Department mentioned in footnote 4 and extending from 1905 to the present time. All have appeared as appendixes to the reports of the U.S. Commissioner of Fisheries. The titles and authors were as follows: (1) The Commercial Fisheries of Alaska in 1905, by John N. Cobb. (2) The Fisheries of Alaska in 1906, by John N. Cobb (accompanied by a report on inspection of the Salmon Fisheries by H. M. Kutchin). (3 to 6) Fisheries of Alaska in 1907, 1908, 1909, and 1910, by M. C. Marsh and John N. Cobb. (7 and 8) Fisheries and Fur Industries of Alaska for 1911 and 1912, by B. W. Evermann. (9) Alaska Fishery and Fur-Seal Industries in 1913, by B. W. Evermann. (10 to 13) Alaska Fishery and Fur-Seal Industries in 1914, 1915, 1916, and 1917, by Ward T. Bower and Henry D. Aller. (14 to 23) Alaska Fishery and Fur-Seal Industries in 1918, 1919, 1920, 1921, 1922, 1923, 1924, 1925, 1926, and 1927, by Ward T. Bower.

It is realized fully, particularly in view of the nature of the data, that the retention in the tables of all digits down to units is not justified and has no significance. No excuse is made for this inconsistency except that it does not seem to be a matter of particular importance and will do no harm—unless to the sensibilities of some few statistically minded individuals.

In spite of the unsatisfactory nature of the data it is believed that the records here presented are of real value; and that, in spite of their faults, they show the history of these fisheries, over the period covered, sufficiently well to be useful in the management of the salmon resources of Alaska until such time as more adequate information is available. It can at least be said that these data approximate the best that can be had out of the faulty records of the past.

No attempt has been made in part IV to give a general description of southeastern Alaska as a whole or a general account of the history of its fisheries, although this has been done in the preceding parts of this series. This region, however, is so large and conditions so varied that such an attempt would more likely be confusing than clarifying. Such descriptions and historical accounts will, however, be found with the discussion of each major district.

YAKUTAT

The Yakutat district (fig. 1) extends from the west side of Yakutat Bay to the east side of Dry Bay, a distance of approximately 85 miles along the southern shore of Alaska. Eight important salmon rivers flow into the Gulf of Alaska between the limits of the district, all of which are indicated on the map.

The district was not prospected for fish until after 1900, although the natives of the region had been utilizing salmon for many years and had given interesting accounts of the abundance of fish. Early examination of the physical features of the district led to the conclusion that a cannery, which would of necessity be located on Yakutat Bay, could not be profitably operated on account of the difficulty of transporting salmon from the several rivers from which the supply would be secured. An alternative was the building and operation of a railroad to provide a constant supply of fish. The transportation of salmon by boat from these rivers would require staunch vessels capable of withstanding heavy seas along a coast exposed to the full sweep of the ocean and even were these provided there was no assurance that trips could be made at all times. The outlook was discouraging at first, but in 1901 an attempt was made to pickle salmon at Yakutat, although no record of the number of fish so used has been found. The salteries that first operated here were primarily interested in packing herring. However, in 1902, they put up a few hundred barrels of salmon from catches obtained in Ankau River and Slough. In 1904 a cannery was built and made the first pack of canned salmon in this district. A railroad 9 miles in length was also built, connecting the cannery with the Situk River from which a large part of the salmon were obtained, the balance of the catch coming from Ankau and Ahrnklin Rivers. In time operations were extended until all the rivers eastward of the Alsek were included in the fishing grounds of the Yakutat cannery, and each one made important contributions to the Yakutat pack.

The largest river in the district is the Alsek. It is a turbulent glacial stream, rising in the Yukon Territory of Canada and draining a large, ice-covered section of the country on the northern slope of the coast range of mountains. The other rivers rise on the southern slope of the mountain range and, except the Ankau, Situk, and Italio, are of glacial origin. Dangerous River, probably next in size to the Alsek, is a swift, glacial stream, the outlet of a lake which is forming along the

southern edge of Yakutat Glacier. As a salmon stream it is the least important of them all. The Ahrnklin River comes third in size and is less affected by glaciers than Dangerous River. Situk is but slightly smaller, but it is a clear stream and the outlet of several small lakes. The Italio, Ankau, and Akwe Rivers are considerably smaller but are fairly clear streams.

Situk River is by far the largest producer of red, coho, and pink salmon in the Yakutat district. Alsek River leads in the production of kings and also supplies

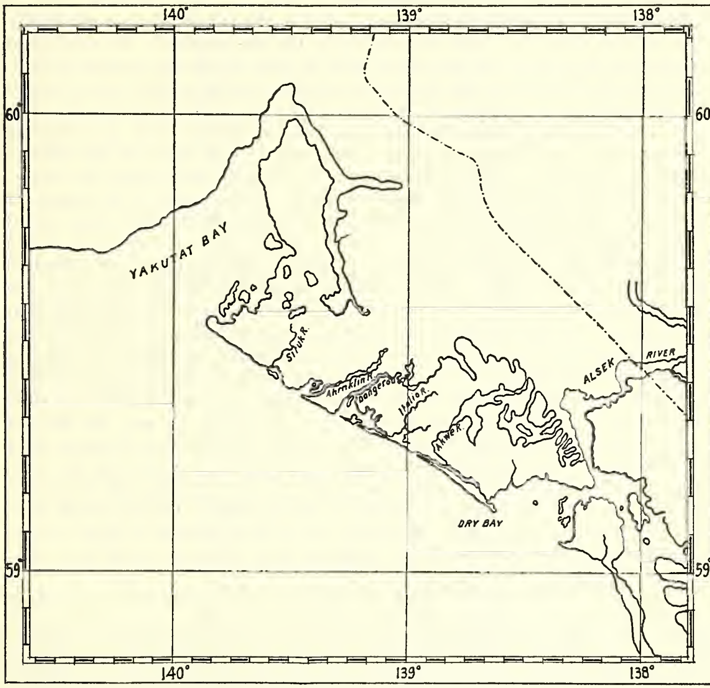

FIGURE 1.—Map of the Yakutat Bay district.

fair catches of reds and cohos. Ahrnklin River has also been a consistent producer of reds and cohos. In fact, all the streams which traverse the glacial moraine between Yakutat and Dry Bays carry moderately good runs of both cohos and reds. Small runs of pinks are found in several of these streams, but the best showing has been made at Humpback Creek, a tributary of Yakutat Bay.

Fishing in the Yakutat district has always been carried on by means of beach seines and gill nets, as all operations are conducted in the rivers and the sloughs which have been formed by the action of the ocean in throwing up bars at the mouths of the several streams, in some cases resulting in the formation of sizable islands.

The fishing grounds, thus protected from heavy surf, can be used uninterruptedly during the entire salmon season. Light-draft boats can be operated in the channels connecting the Ahrnklin and Situk Rivers and the catches from both streams shipped by rail to the cannery, thereby obviating an ocean haul of about 20 miles. Delivery of fish from the more easterly streams can also be made at the same point whenever it is possible to cross the bar at the mouth of Ahrnklin River; otherwise the tenders are obliged to make the run to the cannery. In these quiet waters the fishermen are able to ply their nets without hindrance.

All operations in this field were carried on in accordance with the provisions of the law of 1906 until 1924, when the new fishery law was enacted.[6] No regulations supplementing the general law were issued prior to 1924, though the question of limiting the fishing in Situk River was discussed at a public hearing in 1916; but no further action was taken, as no evidence of depletion of the runs in that river was then produced. In 1924, after passage of the new law, regulations were promulgated, effective June 21, establishing a weekly closed period of 48 hours in that part of the district west of the 139th meridian of west longitude and closing the section of the district east of the same meridian for 20 days from August 11 to August 31 of each year. This regulation was superseded by a new one in 1925 which closed the entire district from July 20 to August 5. In addition, all fishing in Ankau River and Slough, in Akwe River, and in the "Basin" of Alsek River was prohibited throughout the year. These regulations were continued in effect in 1926, and it was further ordered that no fishing boat would be permitted to carry more than 200 fathoms of gill net. In 1927 the limit of gill nets per boat was raised to 250 fathoms, the weekly closed period was extended to 60 hours, and Dry Bay was closed to all fishing before June 1. The size and number of beach seines was not limited in any of these years; gill nets ranging from 200 to 250 fathoms were permitted without limitation as to number except that no boat should carry more than one net. In the end the really effective regulations in permitting a larger escapement of salmon were those establishing closed periods and closed areas. By them alone was the catch reduced, as the unlimited use of seines and of gill nets not exceeding 250 fathoms in length was not likely to result in a slackened fishing effort. Closed periods were effective in breaking the intensity of fishing and making possible a larger escapement of salmon under these protective measures than otherwise would have been the case.

It is evident from the statistical data presented in table 1 that the catch of red salmon at each stream averaged less after 1924 than it did before that date, but there was no decrease in the number of fathoms of seines and gill nets used as compared with the number of nets employed in several seasons immediately preceding. On the contrary, in 1927 more fathoms of seines were operated than in any season since 1916, and the number of fathoms of gill nets used had been exceeded but four times since 1914 (one of which years was 1925 after the regulations under the new law had become operative). While the catch of reds was reduced, cohos were taken in larger numbers in 1927 than in any other year in the entire history of the district; pinks have been captured in greater quantities in the last 5 years than ever before, and there was no material decline in the catch of kings except at Dry Bay in 1927, a fact traceable, in all probability, to the prohibition of fishing prior to June 1. Chums have never constituted an important element in the commercial fishery in the Yakutat district.

[6] See pt. I, p. 47 f.f.

TABLE 1.—*Salmon caught and fishing appliances used in the Yakutat district, 1902 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Gill nets	
						Number	Fathoms	Number	Fathoms
Alsek River and Dry Bay:									
1908				6,769					
1910	29,891	1,786		2,340	6,770				
1911	33,028	13,679	26,261	316	62,133				
1912	24,579	1,580	25	2,098	28,433				
1913			10	4,066	22,013				
1914				11,500	1,253				
1915				8,340	15,485				
1916				386	46,838				
1917	44,905		16	14,372	82,578				
1918	38,877			11,708	126,630				
1919	26,030			13,031	76,098				
1920	15,375			22,882	68,120				
1921	22,002			10,683	50,701				
1922	9,092			7,257	40,044				
1923	23,251			14,228	30,070				
1924	27,891		1	19,055	29,821				
1925	20,143	2	177	19,130	36,262				
1926	15,046			16,824	17,394				
1927	33,539		2	8,153	18,277				
Ankau River and Slough:									
1904	43,788		11,722		41,024				
1905	17,811		96		59,068				
1906	27,497		7,317		32,133				
1907	40,010		26		47,870				
1908	19,742		1,026		55,006				
1909	35,218		603		33,636				
1910	31,173		127		34,750				
1911	39,800		7,612		54,103				
1912	19,395				28,891				
1913	4,756		1,000		17,137				
1914	4,889		404		21,265				
1915	8,553		46,243		16,244				
1916	3,255				13,258				
1917	13,376		1,194		15,681				
1918	3,751		91,762	38	14,299				
1921	7,380		503	24	9,699				
1922	4,025			23	5,756				
1923	859		1,795	17	5,614				
1924			3,987	23	6,013				
1925	79		881	82	5,868				
Ahrnklin River and Slough:									
1904	19,410				30,209				
1905	14,722				7,627				
1906	12,315		2,504		40,080				
1907	17,495		1,052		26,926				
1908	11,690		1,028		63,900				
1909	17,234		1,367		78,081				
1910	49,778		1,096		56,352				
1911	23,629		6,653		130,629				
1912	28,387				113,982				
1913	36,607		1,505		62,489				
1914	39,623		236		65,665				
1915	49,441				54,669				
1916	32,973				28,346				
1917	35,268				39,669				
1918	46,796		1,094	290	33,857				
1919	59,224		837	85	41,110				
1920	50,664		1,384	46	47,266				
1921	31,813		1,593	99	43,171				
1922	25,897		1,197	451	34,905				
1923	21,306		6,901	234	37,540				
1924	16,777		3,266	189	23,396				
1925	23,883	7	330	151	8,474				
1926	15,768		1,005	148	19,058				
1927	56,995		3,034	103	16,858				
Akwe River:									
1910	7,545	325			9,461				
1911	17,215		206	12	11,828				
1912	10,142	96	47	3	10,855				
1913					8,000				
1918	16,708			19	20,299				
1919	20,789			1	16,074				
1920	9,258		78		17,933				
1921	16,362		2	1	10,635				
1922			84	9	10,304				
1923	9,764		1,938	3	7,073				
1924	8,859		237	15	8,024				
Black Sand Island:									
1907	7,160		1,239		17,643				
1908	4,461		1,031		39,144				
1909			1,031		53,489				
1910	6,441		1,642		43,369				
Dangerous River:									
1926	5,312								
1927	10,623		2	2	2,087				
Disenchantment Bay:									
1912			14,628						

TABLE 1.—*Salmon caught and fishing appliances used in the Yakutat district, 1902 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Gill nets	
						Number	Fathoms	Number	Fathoms
Divide Head:									
1914	7,848		130		27,074				
1915	8,896				27,866				
Doane River:									
1912	2,456		616	7	5,723				
1920	486		2,837						
East River and Salt Lake:									
1912	5,824	4,691		2,625	18,634				
1920				588	4,282				
Humpback Creek:									
1904			79,723						
1905			19,086						
1910			2,825						
1911	2,911		66,721						
1913			4,900						
1917			57,530						
1922	42		39,423						
1923	79		64,876		445				
1924	1,860		212,407		27				
1925	204	5	69,579		502				
Italio River:									
1910			3,374		9,531				
1911					4,268				
1912	13,589	51	173		17,744				
1913					20,000				
1916	29,020				28,682				
1917	22,380		6,493		33,168				
1918	28,563		1,565		31,106				
1919	19,941		757		22,457				
1920	23,008		1,571		39,686				
1921	34,545				23,268				
1922	29,087		2,181		22,723				
1923	25,901		4,652		22,750				
1924	19,945		12,669		11,834				
1925	23,437	66	936		11,979				
1926	33,875	4,122	7,751		12,990				
1927	40,679	1,079	16,171		11,191				
Lost River:									
1913	23,499		1,202		24,908				
1914	23,790		776		39,372				
1915	37,062				22,980				
1916	22,570				32,810				
1917	31,453		2,319		25,424				
1918	30,726		1,624	20	20,235				
1919	38,983		994		38,288				
1920	42,209		1,810	39	24,823				
1921	29,552		1,636	60	27,386				
1922	46,342		1,765	50	18,554				
1923	32,708	647	13,025	84	30,553				
1924	30,552		8,482	51	29,301				
1925	24,405	621	3,842	80	16,886				
1926	20,937		3,239	63	17,172				
1927	46,065		11,057	40	15,184				
Monti Bay:									
1912	1,227				7,520				
1916			38,329						
1919	5,391		5,645	14	13,378				
1925	2,110	7	12,337	64	1,088				
1927	11,889		6,849	92	6,425				
Situk River:									
1904	33,342		19,655		70,420				
1905	17,356		26,047		199,969				
1906	40,974		53,428		223,913				
1907	35,947		26,826		238,957				
1908	10,431		21,102	121	271,351				
1909	13,624		15,460		317,463				
1910	37,577		32,759		304,730				
1911	40,108		73,244		243,414				
1912	21,684		3,769		405,737				
1913	47,348		36,820		407,664				
1914	40,144		4,074		389,298				
1915	53,015		111,124	836	295,842				
1916	39,008		3,105	931	285,128				
1917	41,269		25,205	2,499	296,828				
1918	59,464		19,886	746	207,296				
1919	73,860		15,890	231	286,353				
1920	61,280		23,543	736	270,336				
1921	56,094		30,633	1,853	347,754				
1922	65,033		27,912	1,667	244,712				
1923	73,071	5,616	201,238	1,527	225,747				
1924	48,031		69,878	1,162	286,666				
1925	53,424	1,516	15,760	936	119,542				
1926	49,127		15,133	1,703	135,218				
1927	92,537		60,347	1,584	171,648				
States River:									
1921			600						

TABLE 1.—*Salmon caught and fishing appliances used in the Yakutat district, 1902 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Gill nets	
						Number	Fathoms	Number	Fathoms
Yakutat Bay:									
1906					771				
1907	278		24,719						
1908			29,886		1,449				
1909	1,649				426				
1910	1,887								
1911	1,358		52		1,954				
1912			12,257						
1920	8,873		13,208	8	13,381				
1923	3,380								
1924	1,363		120						
1926	3,473	34	218,763	254	5,564				
1927	1		2,800		5				
Unallocated:									
1902	12,300		35,000	150	52,900				
Total:									
1902	12,300		35,000	150	52,900	5		1	
1904	96,540		111,100		141,653	12		10	
1905	49,889		45,229		266,664	8		2	
1906	80,786		63,249		296,897	6		6	
1907	100,890		53,862		331,396	6		14	
1908	46,324		54,073	6,890	430,850	8	480	26	2,600
1909	67,725		18,461		483,095	5	500	20	2,000
1910	164,292	2,111	41,823	2,340	464,963	13	1,200	92	4,500
1911	158,049	13,679	180,749	328	508,329	13	1,200	110	5,500
1912	127,283	6,418	31,515	4,733	637,519	15	1,800	182	9,100
1913	112,210		45,437	4,066	562,211	13	1,400	95	9,500
1914	116,294		5,620	11,500	543,927	15	1,800	70	3,500
1915	156,967		157,367	9,176	433,086	12	1,288	60	4,200
1916	126,826		41,434	1,317	435,062	12	1,728	100	5,000
1917	188,651		92,757	16,871	493,348	12	1,200	200	20,000
1918	224,885		115,931	12,821	453,722	10	1,200	141	7,050
1919	244,218		24,123	13,363	493,758	9	990	83	13,275
1920	211,153		44,431	24,299	485,827	10	1,000	144	7,200
1921	197,748		34,967	12,720	512,614	7	700	70	12,250
1922	179,518		72,562	9,457	376,998	7	700	139	7,275
1923	190,319	6,263	294,425	16,093	359,792	13	1,055	161	7,580
1924	155,278		311,047	20,495	395,082	12	1,120	133	7,160
1925	147,685	2,224	103,842	20,443	200,601	9	950	119	12,071
1926	143,538	4,156	245,891	18,992	207,396	8	720	86	7,860
1927	292,328	1,079	100,262	9,974	241,675	8	1,250	48	7,894

NOTE.—No catches were reported in the years not shown in any division of the table. 1 purse seine was reported as used in 1905 and in 1912.

Figures 2 to 8 are graphs of the catches of salmon at Ankau River and Slough, Situk River, Ahrnklin River, Italio River, Akwe River, Alsek River and Dry Bay, and Lost River. Figure 9 is a graph showing the catch of coho and pink salmon in the Yakutat district as a whole and figure 10 shows the catch and trend of the red-salmon fishery in the district, while the percentage fluctuations from the trend [7] for this species are presented in figure 11.

A careful inspection of these graphs will show a number of interesting things relative to the salmon runs of the Yakutat district. In the first place there appears to be no correlation in size of catch of either cohos or reds (the two most important species here) between different streams, a fact which indicates that both the fisheries and the runs are quite independent. This is true both in respect of the general trends and of the minor fluctuations about these trends. Although graphs have not been made of the catches of the other species it is evident from an examination of the tables that these also show no correlation in the runs in different streams.

Neither have we been able to discover any evidence of periodicity in the runs of any of the species to any of the streams. Even in the case of the pink salmon the fluctuations appear to be erratic and without significance. In many localities elsewhere the pinks show a definite 2-year cycle, a larger run occurring either on the odd or the even year. There is some slight indication of such a cycle in the

[7] See pt. I, pp. 61–63.

catches of pink salmon in the Ankau and also in the Situk, but it is by no means clearly shown and when apparent appears to prevail for only a relatively few years. Periodicity in the runs of red salmon have been very commonly observed, but is not apparent in the Yakutat district either in the separate streams or when the catches of this species are considered for the whole district. Nothing is known of the age groups making up the run of salmon in any year. It is not known whether the Yakutat reds are 4-year fish or more than that age; nor is it known what differ-

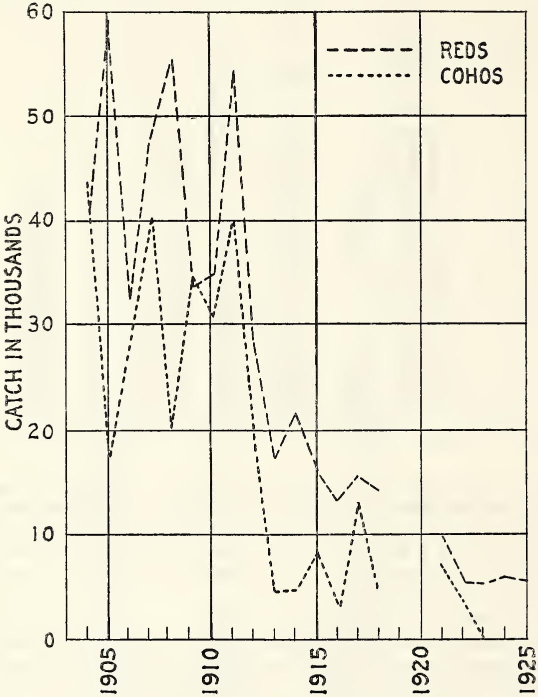

FIGURE 2.—Catch of reds and cohos at Ankau River and Slough.

ence, if any, exists in the age of red salmon of Situk River and those of Ahrnklin River, or the other rivers of the district.

Considering the district as a whole the largest catch of red salmon, which is the most important species in the district, was 637,519. This was made in 1912 by the use of 1,800 fathoms of beach seines and 9,100 fathoms of gill nets. Five years later the catch was 493,348 reds, a decline of more than 22 percent, but the fishing effort had changed by a drop of 33 percent in the number of fathoms of seines and an increase of 119 percent in the number of fathoms of gill nets. The average length of each seine in 1912 was 140 fathoms; in 1917 it was 100 fathoms. In 1912, gill

nets averaged 50 fathoms in length, while in 1917 the average length was 100 fathoms. Comparing these figures with similar ones for 1927, the last year covered by this review, it is found that the average length of seines is 156 fathoms and that of gill nets 164 fathoms. In proportion as the opportunity to fish is restricted, the intensity of fishing has obviously been increased in an effort to maintain the catch and defeat the very object of applied conservation measures. One of the striking things in this connection is the relatively slight deviation from the trend of the catch of red salmon shown in figure 11. These deviations are by no means as great as has been commonly found in other districts. At first sight this would appear to indicate that the supply has been comparatively constant except as affected by the long-time trend. This interpretation, however, is not borne out by an inspection of

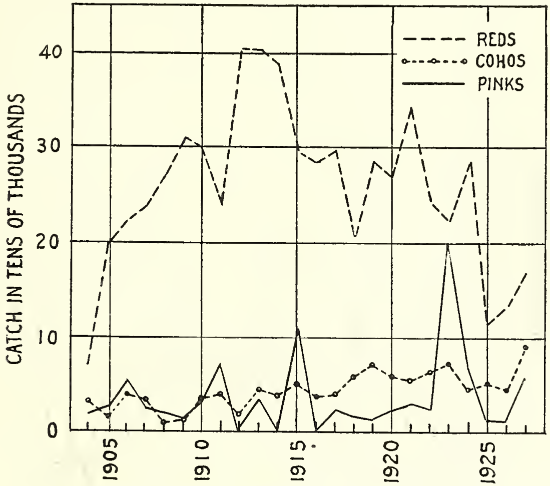

FIGURE 3.—Catch of reds, cohos, and pinks at Situk River.

the data bearing on the catches in the separate rivers. These have fluctuated quite violently but whether from actual changes in the abundance of fish or from changes in the intensity of fishing it is impossible to say. That there were not greater deviations from the trend is surprising, but may have been due to chance or, more probably, to adjustments of fishing effort so that the streams where the better supply of fish were to be found were more heavily fished.

It is certainly true, however, that there is clear evidence of depletion, particularly of the red salmon, in several of the streams and in the district as a whole. The reduced catches during the last few years considered in this review, since the newer conservation measures began in 1924, have doubtless been affected by the regulations; but even before this it is quite apparent that the catches were gradually becoming smaller. The depletion of the runs of both reds and cohos had gone far at the Ankau River as far back as 1913. The Situk has apparently held up well and there is little, if any, evidence that the catches had been reduced materially before

the new regulations became effective. The catches in the 3 years 1925 to 1927 were, however, considerably below the level that had been maintained since 1905. In the Ahrnklin River the catches of red salmon have steadily declined from the peak year of 1911 to 1927. In the Alsek the fluctuations were very wide during the early history of the fishery (perhaps due to faulty data but probably on account of fluctuations in fishing effort) and it is difficult to say whether the catches up to

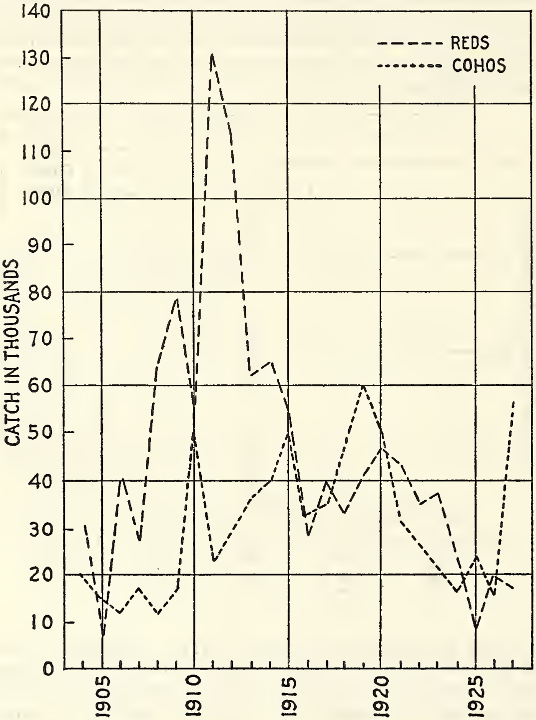

FIGURE 4.—Catch of reds and cohos at Ahrnklin River and Slough.

1925 showed marked reduction or not, although it appears rather probable that they did. The data on the other streams, Italio, Akwe, and Lost Rivers, show no very marked tendencies.

The evidence of depletion in certain of these streams is borne out by the evidence of general depletion in the red-salmon runs of the district as a whole. The data and a moving-average trend are shown in figure 10. From this it is apparent that moderate reduction in catch had already occurred by 1925 at which time the regulations first became really effective. The situation as regards the red-salmon

runs of Yakutat does not appear, however, to be as serious as in many other districts and it may reasonably be expected that the present regulations will prevent serious depletion.

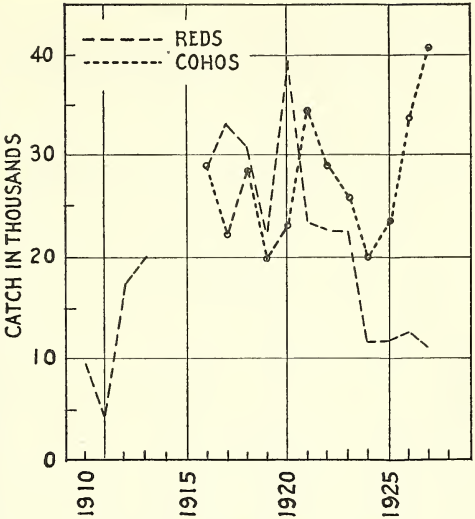

FIGURE 5.—Catch of reds and cohos at Italio River.

ICY STRAIT

The Icy Strait district includes the coastal waters of southeastern Alaska from Lituya Bay on the west to Point Urey on the east side of the southern entrance to Lisianski Strait and the inland waters of Cross Sound and Icy Strait to a line from Point Couverden on the mainland to a point on the north shore of Chichagof Island about 3 miles west of Point Augusta, with all their tributary bays, inlets, and streams. The boundaries of the district are definitely indicated on the accompanying map shown as figure 12. Within it are 47 major localities which have been treated separately in the statistical table. There were 33 other localities mentioned in the records but these have been combined with those that geographically included them or to which they are closely adjacent. In most cases the data for these unimportant localities covered only one or two years, or widely separated years, and therefore had no significance worthy of individual consideration. Moreover, the catches were usually so small, or made so long ago as to have no present value as separate items; but where localities that have been recently developed and

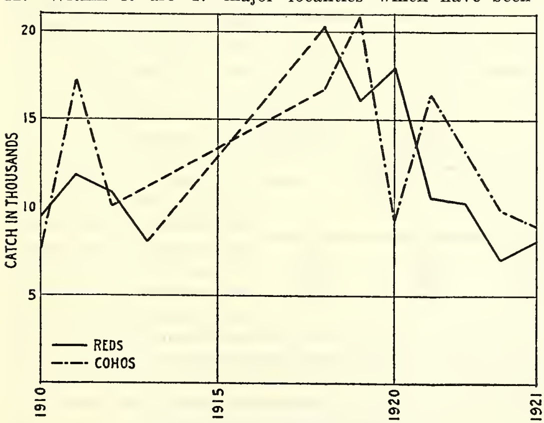

FIGURE 6.—Catch of reds and cohos at Akwe River.

which give promise of continued exploitation have appeared in the records their identity has been preserved.

According to available information, the canning of salmon began in this district in 1889 at Bartlett Cove on the eastern side of Glacier Bay near the Beardslee group of islands. A saltery had previously been operated there but no record of the date of the establishment of the saltery or of the pack it made can now be found. However, the catch probably consisted of a few thousand red salmon taken in the cove directly at the mouth of the creek or actually in the stream. The cannery did not operate after 1891, and from that year to 1899, inclusive, the fisheries of the Icy Strait district seem not to have been exploited.

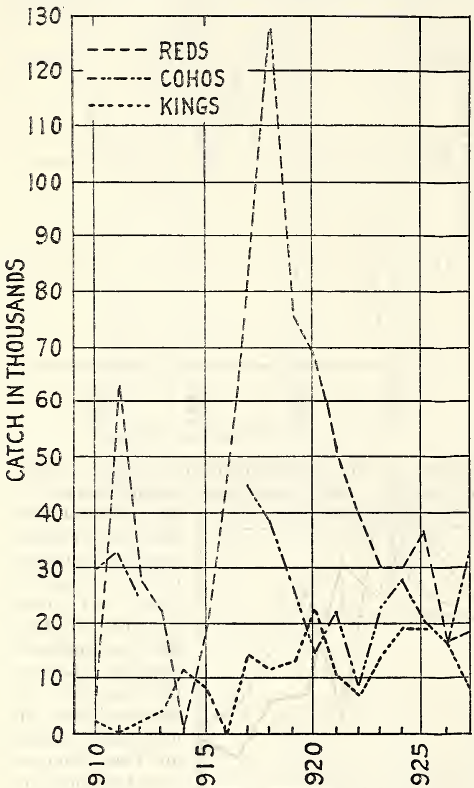

FIGURE 7.—Catch of reds, cohos, and kings at Alsek River and Dry Bay.

In 1900, exploitation of these fisheries was resumed and in a few years expanded rapidly so that practically every stream in the district was known and fished. The number of canneries increased rapidly, and the character of the fishery changed from one conducted primarily by means of beach seines and gill nets to one in which there was a preponderant use of traps and purse seines. By 1915, the shores of Icy Strait especially were lined with traps which had then become the most effective appliances in use. Beach seining was not entirely discontinued, but it was chiefly in the hands of natives whose operations were carried on in the bays near the mouths of streams. Later, with the increase in competition for salmon, larger nets and boats were used and beach seines were largely supplanted by purse seines. The preferred and most successful method of fishing, however, was permanently centered in the operation of traps. Salmon coming in from the ocean through Cross Sound pass close to the conspicuous points of land on both the mainland shores and the islands and these

points constitute advantageous locations for traps. This condition is more pronounced in the section west of Glacier Bay and Mud Bay. East of these bays the shores are more regular and salmon follow them more closely, making trap fishing very productive along the north shore of Chichagof Island, the southern shore of Pleasant Island, and the south shore of the mainland between Excursion Inlet and Point Couverden.

For purposes of review, the district has been divided into three parts, (1) outside localities, (2) Cross Sound and its connecting bays, and (3) Icy Strait proper and its tributaries. The outside localities are Lituya Bay, Dixon Harbor, Surge Bay, Takanis Bay, Hoktaheen Cove, Icy Point, Lisianski Inlet, Lisianski Strait, Stag Bay, and Soapstone Harbor. The runs of salmon to these places, except possibly Lisianski Inlet, are entirely separate and unmixed with the salmon of Cross Sound and Icy Strait. The Cross Sound localities are Port Althorp, Bartlett Cove, Berg Bay, Cross Sound, Dundas Bay, Dundas Point, Goose Island, Gull Cove, Idaho Inlet, Inian Islands, Inian Cove, Inian Pass, James Bay, Lemesurier Island, Mud Bay, North Inian Passage, Salmon Beach, Shaw Island, South Inian Passage, Cape Spencer, Taylor Bay, and Three Hill Island. The Icy Strait localities are Point Adolphus, Division Point, Eagle Point, Excursion Inlet, Port Frederick, Groundhog Bay, Pinta Cove, Pleasant Island, Porpoise Island, Point Sophia, Inner Point Sophia, Spasskaia Harbor, The Sisters, Swanson Harbor, and Whitestone Harbor.

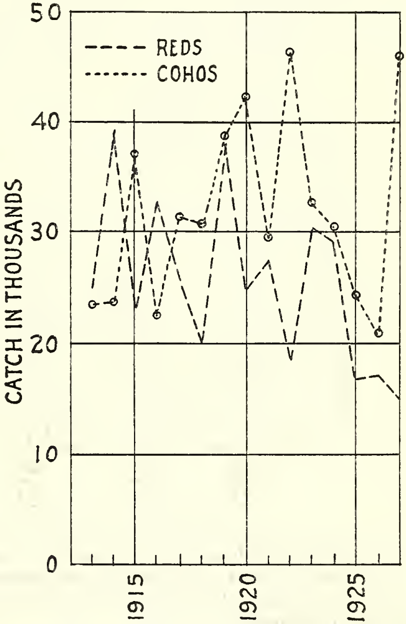

FIGURE 8.—Catch of reds and cohos at Lost River.

Fishing in these several localities was virtually unrestricted before June 26, 1906, as the only regulation which affected the catch was the order of January 5, 1903, which prohibited fishing until July 1 in all southeastern Alaska. This order was rescinded, however, on April 18, 1904, so that the restriction, whatever its value may have been, was applicable in but one season. It may have reduced somewhat the catch of red salmon in this district in 1903, as that species makes its appearance in June, yet the small amount of fishing gear in use and the few operators engaged in fishing at that time could have taken comparatively few additional salmon had the restriction not been imposed. This is clearly shown by a comparison of the catch in 1903 with that in 1902 when fishing was unregulated and more gear was used than in 1903. When the law of 1906 became effective, the placing of barricades at points in streams where

the distance from bank to bank was less than 500 feet was made unlawful. Red-salmon streams were also protected against fixed appliances to a distance of 500 yards outside the mouths. The interesting point in this connection is that only red-salmon streams were protected at their mouths. In other words, there was no legal prohibition against operating a trap or any other fixed fishing appliance directly in the mouth of any stream not classed as a red-salmon stream. The same law prohibited the placing of movable fishing gear in any stream, estuary, or lagoon across more than one third of its width, or within 100 yards outside the mouth of any red-salmon stream less than 500 feet in width. The lateral and endwise distance between traps was also prescribed by law. Under these provisions, protection was given very largely to red salmon in so far as restriction of fishing in or at the streams was involved. A weekly closed period of 36 hours in all localities in southeastern Alaska and a daily

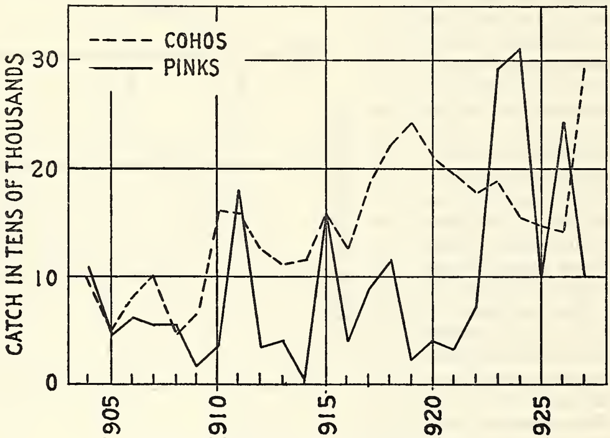

FIGURE 9.—Catch of cohos and pinks in the Yakutat district.

closed period of 12 hours for all streams less than 100 yards in width were provided in the hope that this would increase the opportunities for salmon to ascend to the spawning grounds. Undoubtedly these provisions had a direct effect upon the catches of all species.

On December 21, 1918,[8] all commercial fishing for salmon in streams less than 500 feet in width and within 200 yards of the mouths of all salmon streams was prohibited; traps and other fixed appliances were not permitted within 500 yards of the mouths of such streams. Thus, for the first time, general regulations affecting indiscriminately all species of salmon were promulgated.

In 1920 the regulations were broadened by extending protection to all salmon streams regardless of width and to a distance of 200 yards outside the mouths of such streams. They also prohibited the operation of fixed fishing appliances within 500

[8] This order was published in Department of Commerce Circular No. 251, fifth edition, Jan. 14, 1919, but was inadvertently omitted from part I of this review.

yards of the mouths of salmon streams. All streams west of Cape Spencer were protected against all appliances to a distance of 500 yards.

The next change in the regulations was made on January 1, 1922. It prohibited all fishing in the streams and within 500 yards of the mouths of salmon streams, thus rescinding the exceptions in favor of movable appliances provided in the order of 1920.

On June 6, 1924, the new law giving vastly larger powers to the Secretary of Commerce in the protection of the salmon fisheries of Alaska became effective. Its authority was immediately applied to the issuance of regulations designed to secure a

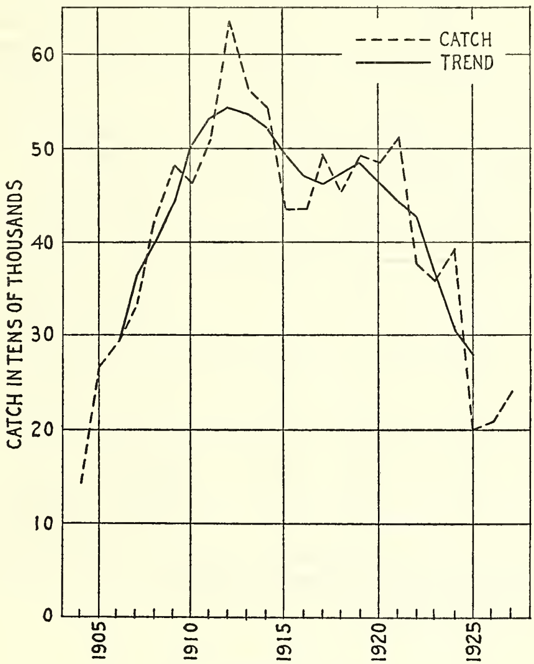

FIGURE 10.—Catch of reds in the Yakutat district.

larger escapement of salmon into the streams. In the Icy Strait district all fishing was prohibited for 20 days, from August 11 to 31.

In 1925 all fishing was prohibited after August 6, except trolling, and gill netting from September 5 to October 15; the distance interval between traps was fixed at not less than 1½ miles; no fishing boat was permitted to carry more than one seine; Port Frederick was partially closed, while Glacier Bay was completely closed.

In 1926 further restrictions were imposed. Gill nets were limited to 200 fathoms in length; purse seines to 250 fathoms; and Dundas Bay north of 58° 21′ was closed.

Regulations for 1927 increased the length of gill nets to 250 fathoms, closed Port Frederick south of Inner Point Sophia, except to gill nets which were permitted to operate to June 1. On April 27, 1927, the order affecting Port Frederick was rescinded in part and the order of 1925 was restored.

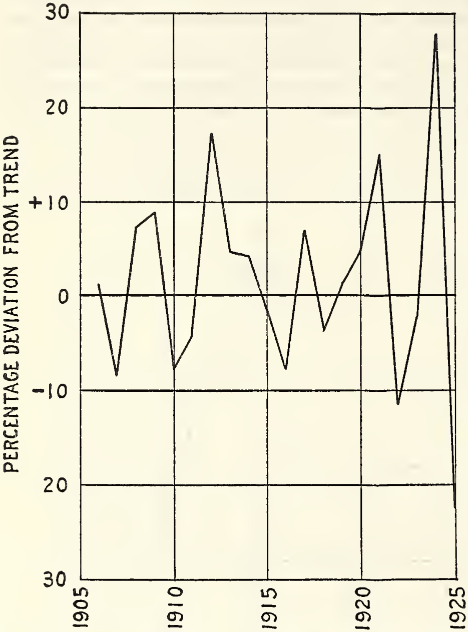

FIGURE 11.—Percentage deviation from trend of catch of red salmon in Yakutat district.

In view of the fact that all regulations promulgated before 1924 were more or less general in character, it seems probable that the effect upon the catch was much the same in all localities, but with the application of the more specific regulations in 1924 and subsequent years, certain localities should show a material reduction in catch, more especially the bays in which seining had been done near the mouths of streams. The requirement of a distance interval of 1½ miles between traps probably reduced the catch along some shores but only to make it better in other places, while it was practically without effect upon the catch of traps in isolated positions. The most effective regulations were unquestionably those providing closed periods, especially seasonal closures. The weekly closed periods were probably less effective, as 18 years of unbroken application seems not to have retarded the general decline in the catches.

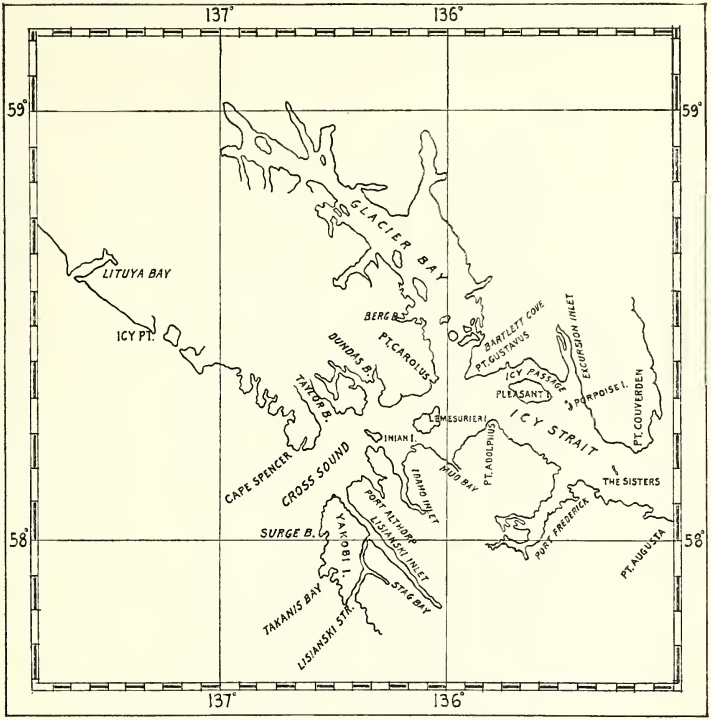

FIGURE 12.—Map of the Icy Strait district.

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Adolphus, Point:												
1913	122	518	1, 249		189							
1915	389	1, 498	15, 576	79	1, 976							
1917	261	3, 541	101, 218	32	5, 428							
1918	47		152	1	21							
1919	45	1, 516	4, 548	32	1, 216							
1920	474	12, 466	43, 429	69	7, 303							
1923	1, 119	21, 774	162, 868	12	13, 185							
1924	5, 129	66, 022	148, 793	45	31, 756							
1925	4, 390	73, 464	220, 379		38, 004							
1926	7, 825	73, 320	419, 333	9	47, 183							
1927	17, 232	139, 434	446, 037	12	46, 499							
Althorp, Port:												
1905			9, 431									
1908		7, 082	3, 364									
1909		1, 165	46, 312									
1910			20, 993									
1913	730	4, 250	25, 022	4	185							

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Althorp, Port—Continued.												
1914	845	3,082	16,351		923							
1915	5,248	20,800	307,471		30,688							
1916	19,463	87,248	567,524	779	58,415							
1917	6,557	53,827	269,889	1,188	21,633							
1918	4,482	120,413	262,780	721	12,733							
1919	2,291	47,826	43,083	224	36,289							
1920	3,135	20,910	23,050	249	3,160							
1921	5,796	3,603	3,830		72,873							
1922	625	5,015	27,375	12	3,059							
1923	449	3,281	78,395	13	4,611							
1924	2	2,986	11,746		652							
1925	899	9,369	27,308	13	2,040							
1926	1,861	11,799	110,423		3,929							
1927	4,815	7,037	100,872	17	5,249							
Bartlett Cove:												
1905	1,546	364	208		9,783							
1906	5,314	371	3,520		11,305							
1907	191		3,404		7,514							
1908	254	674	880		7,990							
1909			149		13,334							
1910	3,358	2,133			8,933							
1911	5,468				21,191							
1912	4,408	1,087	351		9,122							
1913	317	906	4,193		8,729							
1914	3,032	745	74		10,079							
1915		1,264	3,756		12,256							
1917		2,172	978		7,015							
1918	2,844	3,527	1,864		11,460							
1919	2,201	1,167	177	48	2,965							
1920	184	240	301		2,923							
1922	584	298	563	48								
1923		8	336		2,910							
1924	3,615	1	103		1,665							
Berg Bay:												
1922	1,141	87	380		1,327							
1923		7	92	3	1,378							
1924	5	452			37							
Cross Sound:												
1911	6,331		95,582		37,768							
1912	41,653	96	48,481	41	20,411							
1913	5,811	6,730	49,559		15,628							
1914	4,804	27,033	76,322	283	44,951							
1915	4,978	3,354	51,484	381	21,157							
1916	11,589				21,159							
1917	313	13,764	101,054	55	3,073							
1918	1,118	1,556	9,043	12	1,066							
1919	690	1,743	4,797									
1920		657	586		119							
1921		1,023	2,207									
1923	1,271	3,781	27,068	2	9,286							
1924	1	418	34,177		411							
1925	28	2,260	2,395		270							
1926	1	266	2,695		4							
1927	24,670	77	1,411	3	1,380							
Division Point:												
1926	1,935	8,056	111,839		12,744							
1927	1,312	1,489	36,256		3,468							
Dixon Harbor:												
1908					4,253							
1909					2,901							
1912	21	1,785	1,255		1,711							
1913	338	332	1,933	178	1,870							
1914			4	76	3,070							
1915		4,376	230	84	468							
1918	470	31	191									
1920		169	16		657							
1924			776		112							
Dundas Bay:												
1904					10,000							
1905	2,804	86	18		20,168							
1906	5,793	57			11,489							
1907	8,841	307			21,082							
1908	1,619	5,378	42		32,706							
1909	16	3,963	105,274		43,952							
1910	4,568	139			14,215							
1911	2,646	4,995			10,115							
1912	870	3,215	572		10,628							
1913	253	998	30		7,080							
1914	3,340	785	3		15,630							
1915	832	6,501	11,684	360	37,710							
1916	757	3,130	12,892	300	34,419							
1917	12,036	8,215	25,912	77	38,761							
1918	16,493	20,779	28,979	990	51,282							
1919	15,472	21,398	14,298	168	12,731							
1920	19,074	53,896	97,038	73	31,792							

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Dundas Bay—Continued.												
1921					12,066							
1922	1,696	1,519	1,986		9,965							
1923	5,045	4,526	20,175	85	16,677							
1924	7,008	34,712	23,851	97	43,976							
1925	5,451	32,071	24,577	118	42,094							
1926	3,940	33,941	28,794	31	24,214							
1927	2,580	6,333	12,437	32	6,876							
Dundas Point:												
1922	3,792	6,590	16,540	12	11,070							
1925	2,429	15,921	33,104	4	9,799							
1926	2,412	9,872	41,901	5	5,117							
1927	1,785	3,375	29,385	12	4,836							
Eagle Point:												
1913	9,467	2,294	1,707		423							
1924	2,205	6,031	57,978	57	8,691							
1925	4,382	10,325	45,729	94	9,514							
1926	2,789	14,340	68,028	81	9,867							
1927	3,464	8,365	66,170	322	6,673							
Excursion Inlet:												
1906	418	12,362										
1907		2,025										
1910		69,930										
1911		2,735										
1914	12	1,502			3							
1917	4,965	21,774	76,562	56	6,036							
1918	173	10,682	141		61							
1919	138	8,043	1,106		385							
1920	17,370	143,780	113,204	369	50,722							
1922	1,517	43,569	776		390							
1923	2,039	24,484	24,701		78							
1924	2,397	73,578	17,556	12	2,382							
1925	538	7,428	1,001		3,039							
1926	27	4,678	469		546							
1927	609	4,023	25,586		2,469							
Frederick, Port:												
1905			21,000									
1906	25											
1907			7,375									
1908		95	37,078									
1909			38,332									
1910		3,150										
1911		10,668	205,801									
1912	5,095	113,014	16,909		701							
1913	212	20,098	127,840		256							
1914	4,000	36,632	21,054		275							
1915		28,726	62,311		34							
1917	6,761	63,480	185,473	37	2,453							
1918	5,812	42,235	40,051	4	1,547							
1919	1,886	51,374	24,043	106	2,440							
1920	1,462	28,281	34,094	54	679							
1922	143	2,871	8,694									
1923	226	30,770	144,734	2	2,307							
1924	127	119,808	44,636	9	1,126							
1925	54	45,108	4,698		31							
1926	109	26,680	24,915		442							
1927	4,024	10,122	18,157	398	2,757							
Goose Island:												
1926				355								
1927				424								
Groundhog Bay:												
1916	17,655	12,508	4,248		3,022							
1924	2,552	12,798	55,184	34	10,971							
1925	3,776	22,545	40,494	50	20,286							
1926	2,370	17,650	60,885	19	16,428							
1927	1,150	9,095	38,245	69	12,194							
Gull Cove:												
1913	9,521	9,927	40,937	24	4,968							
1914	1,295	2,696	14,218	323	7,522							
1924	3,119	7,329	83,086	159	9,118							
1925	4,998	14,296	49,933	131	10,591							
1926	6,181	16,085	228,583	195	17,150							
1927	4,313	8,411	100,016	312	8,454							
Hoktaheen Cove:												
1905	270		6,250		8,279							
1906			15,807		11,348							
1907					7,000							
1908			1,325		10,677							
1909			11,311		10,391							
1910					9,896							
1911					7,196							
1912	646	227	52		7,197							
1913	597	1,265	4,760	27	5,344							
1914	699	712	1,374	20	7,686							
1915	4	460	4,129		8,301							

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Hoktaheen Cove—Contd.												
1918	682	162	1,890		2,519							
1919	536	273	218		5,463							
1920	1,644	446	744	7	3,218							
1922		933			653							
1923	303	11	322		5,266							
1924			12		2,310							
1925	2	72	5	2	2,335							
1926	1	38	436	1	1,834							
1927	16	196	311		2,021							
Icy Point:												
1914	4		2	36	2,505							
1915			280	1,529	9,225							
Idaho Inlet:												
1908		172	118									
1912		772	399		354							
1913	9,038	17,847	74,930		5,848							
1914	25	6,609	3,108		1,077							
1917	5,734	11,806	22,832	3	1,465							
1918	1,018	10,845	6,086	1,099	1,178							
1919	96	4,643	581	85	184							
1920	656	13,589	3,370	104	560							
1922	361	3,474	1,909		24							
1923	245	799	2,088		214							
1924	299	14,369	9,449	17	1,596							
1925	35	5,472	4,939		491							
1926	9	3,056	3,338	2	2,708							
1927	20	1,715	2,416	3	75							
Inian Cove:												
1915	601	3,269	36,222	207	4,110							
1916	1,200	3,286	53,825	100	4,141							
1917	5,178	5,194	135,063	68	4,679							
1920	310	16,834	45,706	30	6,232							
1922	4,732	14,315	69,821	6	17,290							
1923	694	4,497	20,239	19	4,834							
1924	2,495	22,384	175,972	1	22,132							
1925	2,103	28,408	45,411	1	5,051							
1926	7,471	47,245	258,089	11	38,608							
1927	4,714	22,812	173,280	18	13,993							
Inian Islands:												
1912	32,285	5,722	12,492		2,501							
1913	2,120	1,343	5,020		462							
1914	2,783	5,910	30,103	75	19,622							
1918	13,211	17,569	51,514	2,078	10,249							
1919	185	44,384	96,418	250	18,994							
1920	5,351	20,858	67,185	102	10,832							
1922					2,462							
1923					488							
1924	5,617	44,973	200,636		36,971							
1925	1,685	39,821	58,259		16,614							
1926	3,351	27,356	122,940	9	10,363							
1927	5,211	26,805	113,881	25	15,192							
Inian Pass:												
1926	1,186	6,722	53,058		3,471							
1927	25	63	1,183		82							
James Bay:												
1905			65		281							
1907	970				4,029							
1908	280	55			4,852							
1909					2,021							
1912	1,924	803			3,136							
1913	563				3,086							
1914	1,327	3			5,704							
1915		36			7,752							
1917		53	570		7,071							
1918	3,974	931	240	1	4,831							
1919	5,584	1,798	1,977	16	2,856							
1920	490	1,131	699		2,505							
1923	303	11	73	4	1,051							
1924		63	138	1	1,139							
Lemesurier Island:												
1913			700		299							
1918	956	845	16,944		1,055							
1919	3,459	11,107	50,443	525	8,212							
1920	1,556	26,545	76,847	41	15,680							
1922	2,207	10,675	43,500	290	11,805							
1923	1,022	5,241	89,570		10,186							
1924	1,206	8,119	25,749		6,817							
1925	1,458	6,410	12,231	5	9,128							
1926	2,711	21,258	64,853	17	13,493							
1927	864	5,042	18,167	16	3,531							
Lisianski Inlet:												
1920	208	1,209	8,363		418							
1922	1,545	6,625	15,097									
1923	1,158	3,828	45,008	10	1,700							
1924	76	2,622	28,189		1,349							

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Lisianski Inlet—Contd.												
1925	200	7,297	22,339	12	4,291	-----	-----	-----	-----	-----	-----	-----
1926	160	2,915	76,659	1	3,184	-----	-----	-----	-----	-----	-----	-----
1927	827	2,979	69,168	63	2,784	-----	-----	-----	-----	-----	-----	-----
Lisianski Strait:												
1905	-----	-----	49,479	-----	124	-----	-----	-----	-----	-----	-----	-----
1906	30	-----	52,523	-----	774	-----	-----	-----	-----	-----	-----	-----
1907	-----	-----	55,936	-----	-----	-----	-----	-----	-----	-----	-----	-----
1908	-----	1,816	6,332	-----	942	-----	-----	-----	-----	-----	-----	-----
1909	872	49	33,917	-----	167	-----	-----	-----	-----	-----	-----	-----
1910	-----	-----	25,382	-----	-----	-----	-----	-----	-----	-----	-----	-----
1911	-----	2,499	106,254	-----	-----	-----	-----	-----	-----	-----	-----	-----
1912	266	593	24,780	-----	98	-----	-----	-----	-----	-----	-----	-----
1913	6	3,782	63,083	-----	274	-----	-----	-----	-----	-----	-----	-----
1914	118	1,468	24,697	-----	1,420	-----	-----	-----	-----	-----	-----	-----
1915	29	-----	33,453	-----	5,862	-----	-----	-----	-----	-----	-----	-----
1916	1,321	3,869	10,565	153	19,021	-----	-----	-----	-----	-----	-----	-----
1917	-----	5,000	21,111	-----	-----	-----	-----	-----	-----	-----	-----	-----
1918	19,573	19,500	164,748	285	9,250	-----	-----	-----	-----	-----	-----	-----
1919	5,446	15,200	37,145	213	8,789	-----	-----	-----	-----	-----	-----	-----
1920	4,310	12,335	6,563	60	4,200	-----	-----	-----	-----	-----	-----	-----
1923	448	1,227	39,842	1	4,905	-----	-----	-----	-----	-----	-----	-----
1924	10	596	15,603	6	1,398	-----	-----	-----	-----	-----	-----	-----
Lituya Bay:												
1905	85	-----	-----	-----	795	-----	-----	-----	-----	-----	-----	-----
1910	-----	-----	-----	-----	7,000	-----	-----	-----	-----	-----	-----	-----
1911	-----	-----	-----	-----	4,000	-----	-----	-----	-----	-----	-----	-----
1912	82	-----	-----	-----	1,474	-----	-----	-----	-----	-----	-----	-----
1913	-----	1,600	570	-----	3,801	-----	-----	-----	-----	-----	-----	-----
1914	-----	-----	-----	-----	5,015	-----	-----	-----	-----	-----	-----	-----
1915	-----	-----	-----	-----	6,302	-----	-----	-----	-----	-----	-----	-----
1917	762	-----	-----	-----	442	-----	-----	-----	-----	-----	-----	-----
1918	1,855	-----	-----	-----	1,969	-----	-----	-----	-----	-----	-----	-----
1919	-----	-----	1	196	79,511	-----	-----	-----	-----	-----	-----	-----
1920	-----	-----	6	-----	5,665	-----	-----	-----	-----	-----	-----	-----
1922	1,351	-----	-----	-----	5,716	-----	-----	-----	-----	-----	-----	-----
1923	2,017	-----	7	-----	5,047	-----	-----	-----	-----	-----	-----	-----
1924	-----	17	423	-----	945	-----	-----	-----	-----	-----	-----	-----
1925	24	32	61	-----	1,284	-----	-----	-----	-----	-----	-----	-----
1926	-----	-----	-----	-----	956	-----	-----	-----	-----	-----	-----	-----
1927	1,263	-----	4	-----	2,056	-----	-----	-----	-----	-----	-----	-----
Mud Bay:												
1912	700	2,924	-----	-----	4	-----	-----	-----	-----	-----	-----	-----
1913	-----	11	44,043	-----	-----	-----	-----	-----	-----	-----	-----	-----
1914	9,241	2,750	74	-----	612	-----	-----	-----	-----	-----	-----	-----
1915	-----	13,516	30,094	-----	-----	-----	-----	-----	-----	-----	-----	-----
1920	1,094	49,744	80,285	93	14,282	-----	-----	-----	-----	-----	-----	-----
1924	291	1,485	11,375	-----	628	-----	-----	-----	-----	-----	-----	-----
1927	16	851	1,010	-----	87	-----	-----	-----	-----	-----	-----	-----
North Inian Passage:												
1923	4,864	19,295	208,635	30	46,058	-----	-----	-----	-----	-----	-----	-----
1924	-----	-----	209	-----	18	-----	-----	-----	-----	-----	-----	-----
1925	502	12,349	32,446	1	4,921	-----	-----	-----	-----	-----	-----	-----
1926	1,386	11,657	63,678	4	6,393	-----	-----	-----	-----	-----	-----	-----
1927	227	2,393	12,725	-----	2,721	-----	-----	-----	-----	-----	-----	-----
Pinta Cove:												
1915	1,429	2,592	27,120	-----	7,320	-----	-----	-----	-----	-----	-----	-----
1920	-----	871	8,317	2	1,325	-----	-----	-----	-----	-----	-----	-----
1926	174	2,594	10,983	-----	2,209	-----	-----	-----	-----	-----	-----	-----
Pleasant Island:												
1904	-----	-----	180,000	-----	-----	-----	-----	-----	-----	-----	-----	-----
1907	-----	1,000	122,006	-----	17,093	-----	-----	-----	-----	-----	-----	-----
1908	6,210	6,210	175,402	-----	20,586	-----	-----	-----	-----	-----	-----	-----
1911	1,230	2,080	4,358	-----	2,060	-----	-----	-----	-----	-----	-----	-----
1918	30,350	67,450	700	-----	1,600	-----	-----	-----	-----	-----	-----	-----
1919	66,729	65,495	197,422	34	-----	-----	-----	-----	-----	-----	-----	-----
1920	33,850	71,804	202,113	105	48,360	-----	-----	-----	-----	-----	-----	-----
1922	30,657	28,635	188,318	10	54,181	-----	-----	-----	-----	-----	-----	-----
1923	801	6,459	49,594	28	4,621	-----	-----	-----	-----	-----	-----	-----
1924	16,684	60,407	292,703	150	76,388	-----	-----	-----	-----	-----	-----	-----
1925	9,955	56,072	125,665	25	56,037	-----	-----	-----	-----	-----	-----	-----
1926	7,399	50,675	246,974	274	53,964	-----	-----	-----	-----	-----	-----	-----
1927	10,635	32,176	217,874	22	42,611	-----	-----	-----	-----	-----	-----	-----
Porpoise Island:												
1908	12,114	42,073	184,201	-----	6,546	-----	-----	-----	-----	-----	-----	-----
1922	2,580	2,108	22,627	-----	6,535	-----	-----	-----	-----	-----	-----	-----
1924	7,072	12,804	49,662	-----	20,160	-----	-----	-----	-----	-----	-----	-----
1925	3,631	15,503	42,335	6	19,868	-----	-----	-----	-----	-----	-----	-----
1926	2,579	16,840	74,908	90	17,143	-----	-----	-----	-----	-----	-----	-----
1927	2,755	4,814	58,430	-----	6,994	-----	-----	-----	-----	-----	-----	-----
Salmon Beach:												
1924	-----	1,048	89	-----	3,616	-----	-----	-----	-----	-----	-----	-----
1925	-----	134	181	-----	1,865	-----	-----	-----	-----	-----	-----	-----
1926	8	408	731	1	980	-----	-----	-----	-----	-----	-----	-----
1927	-----	1	35	14	696	-----	-----	-----	-----	-----	-----	-----

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Shaw Island:												
1917	79	1,424	19,544	11	1,391							
1926	915	3,320	17,939	4	1,566							
Soapstone Harbor:												
1908	101	755	2,884		20							
1912	121	894	23		126							
1913			3,615									
1919		79			356							
1924			1,890		452							
1925	3	1,175	608		644							
1926	4	628	2,403		63							
1927	32	1,846	1,447		152							
Sophia, Point:												
1918	252	1,359	27,111		1,390							
1923	4,914	21,016	146,594	201	11,939							
1924	1,446	10,239	29,515	63	3,589							
1925	2,016	19,351	40,268	70	5,784							
1926	820	27,204	54,771	17	2,708							
1927	1,745	17,593	80,424	58	4,140							
Sophia, Inner Point:												
1926	823	22,745	35,281	8	2,073							
1927	225	6,687	22,450	109	107							
South Inian Pass:												
1926	5,625	28,291	145,913	16	20,190							
1927	3,953	4,188	71,137	16	6,415							
Spasskaia Harbor:												
1916	5,596	16,076	271,693	390	4,590							
1917	252	24,560	427,155	40	3,923							
1918	3,162	7,069	80,189	86	2,741							
1919	422	2,851	6,741	86	1,533							
1920	2,391	14,203	61,480	43	5,724							
1923	296	1,368	30,992	4	1,140							
1924	1,133	7,631	25,506	43	2,060							
1925	3,000	22,282	32,041	61	5,365							
Spencer, Cape:												
1906					2,301							
1908		71	493		7,369							
1909			1,321		6,564							
1910					9,249							
1911					5,765							
1912		26	762		3,829							
1913	177	855	770		1,423							
1914		206	32		6,610							
1915	1		8,569	80	21,266							
1917	571	6,279	55,027	120	21,972							
1918	366	9,704	9,432	182	11,100							
1919	126	2,673	2,214	1,569	14,241							
1920		221	34		2,698							
1922	2,543	694	3,583	102	2,889							
1923	473	305	731	30	5,636							
1924	1	706	10,120		1,378							
1925	14	1,064	440		1,610							
1926	16	424	5,701		4,091							
1927	29	262	415	10	1,689							
Stag Bay:												
1923	50	219	1,204		90							
1924	5	2,179	3,257		243							
1925	275	4,726	7,822	2	1,779							
1926		1,119	10,080		1,301							
1927	87	689	509		183							
Surge Bay:												
1904					10,000							
1905	2,780		1,445		13,193							
1906	2,907		9,922		22,620							
1907		4,445			48,584							
1908	1,523	153	266		49,260							
1909	207		530		25,530							
1910	990				28,504							
1911	3,047	1,441	1,779		20,341							
1912	483	1,716	1,066		10,233							
1913	1,185	112	1,161		9,409							
1914	1,188	44	27	69	13,609							
1915	31	7	9,409		29,840							
1916	541	3,193	2,834		28,083							
1917	2,984	2,472	7,704	19	22,999							
1918	1,718	2,645	4,257	23	25,662							
1919	2,136	1,775	2,820	9	22,532							
1920	527	1,349	1,301	17	14,780							
1922	4,500	769	2,097	5	23,026							
1923	4,400	450	1,872	1	12,473							
1924	624	4,039	2,596		34,223							
1925	183	3,366	4,852	24	27,322							
1926	217	1,454	6,168	1	25,414							
1927	218	1,345	4,582	3	19,652							

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Swanson Harbor:												
1916	3,500	2,888	38,002		4,079							
1920		3,009	4,657									
1921		1,667										
1922		2,623	8,528									
1925	2,202	6,521	2,658	101	2,184							
Takanis Bay:												
1905	1,803		11,287		8,618							
1906	24		1,948		4,193							
1907					2,087							
1908	819		851		10,401							
1909	401		851		8,329							
1910					12,312							
1911	1,178				4,000							
1912	2,080	406	481		8,611							
1913	792	59	1,031		5,175							
1914	2,453	212	702		10,147							
1915	231		1,402		6,117							
1916	3,738	103	127		1,685							
1917	2,658	1,709	7,702		8,562							
1918	363	66	714		4,151							
1919	161	724	1,180	1	6,995							
1920	403	182	278	6	4,309							
1922	64	2,262	2,412		1,334							
1923	3,953	1,641	4,306		15,703							
1924	3,581	294	1,133		9,899							
1925	30	96	341		4,239							
1926	11	1,286	3,853		8,429							
1927					1,166							
Taylor Bay:												
1904					20,000							
1905	13				11,524							
1906					18,755							
1907					56,207							
1908	158		853		43,185							
1909			5,899		11,765							
1910					7,995							
1911					3,900							
1912	9	138	3,051		6,295							
1913	21	500	39		1,261							
1914		1	1		17,369							
1915			326		4,507							
1918	3	61	71		7,275							
1919		432	7		2,936							
1920		4	145		1,986							
1922	3,590	888	3,020		12,105							
1923	664	63	380	6	25,127							
1924	376	4,647	7,116	13	26,216							
1925		149	44	1	1,889							
1926	1	1	105	1	2,128							
1927		69	549		39							
The Sisters:												
1922	1,011	3,675	33,402	15	4,654							
1923	4,155	10,711	83,686	137	35,891							
1924	1,413	8,205	16,604	25	2,793							
1925	4,378	19,626	41,371	63	24,332							
1927	30	53	132		4							
Three Hill Island:												
1927	5,040	8,018	77,922	7	5,284							
Whitestone Harbor:												
1910			21,727									
1918	686	6,329	45,724		2,533							
1924		15	3,402									
1926	625	13,860	63,240	17	1,703							
Unallocated:												
1889 [1]					51,600							
1890 [1]					144,000							
1891 [1]					91,200							
1900 [2]	27,098		65,186	275	151,901							
1901 [2]	11,087		189,701	424	96,547							
1902 [2]	24,458		435,746		218,084							
1903 [2]	37,560		560,176		236,167							
1904	22,000	16,808	256,980		392,262							
1905	27,099	96,783	126,992	21,215	511,510							
1906	101,352	191,727	928,814	2,300	292,674							
1907	94,343	115,773	1,589,444	18,201	347,669							
1908	46,481	240,547	2,369,452	2,636	462,353							
1909	49,662	125,125	842,208	1,740	501,557							
1910	76,128	189,731	970,402	270	511,698							
1911	106,174	379,447	1,763,604	2,857	519,390							
1912	150,066	823,567	1,440,750	8,031	731,731							

[1] Statistics used in this table for the years 1889, 1890, and 1891 were obtained by taking the pack reported by Moser (1902) and multiplying the number of cases by 10, that being the number of red salmon from this district required to pack a case of forty-eight 1-pound cans, according to Moser's calculations.
[2] Data taken from reports of treasury agents.

TABLE 2.—*Salmon caught and fishing appliances used in the Icy Strait district, 1899 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated—Continued.												
1913	108,349	311,393	2,840,169	9,923	610,558							
1914	283,136	601,462	1,718,694	9,232	1,131,048							
1915	98,718	465,973	3,637,092	9,333	554,964							
1916	367,724	762,721	4,282,530	7,044	500,947							
1917	163,185	535,961	6,141,609	8,196	555,867							
1918	187,992	1,060,791	3,551,556	13,996	662,095							
1919	166,172	886,335	1,547,296	8,224	594,051							
1920	122,354	552,486	1,276,547	5,215	368,824							
1921	128,347	215,195	486,242	4,196	186,199							
1922	81,811	214,954	1,305,883	2,330	257,240							
1923	73,318	214,435	2,066,180	1,184	275,205							
1924	79,681	177,112	811,053	3,092	185,572							
1925	59,761	222,265	372,251	3,208	192,700							
1926	21,358	203,129	714,206	741	160,514							
1927	99,445	147,723	644,786	43,645	113,106							
Total:												
1889 [1]					51,600							
1890 [1]					144,000							
1891 [1]					91,200							
1900 [2]	27,098		65,186	275	151,901	14				3		
1901 [2]	11,087		189,701	424	96,547	19				16		2
1902 [2]	24,458		485,746		218,084	25				12		5
1903 [2]	37,560		560,176		236,167	17				3		5
1904	22,000	16,808	436,980		432,262			11				7
1905	36,400	97,233	226,175	21,215	584,275	3		22		2		7
1906	115,863	204,517	1,012,534	2,300	375,459	2		16		2		7
1907	104,345	123,552	1,778,165	18,201	511,265	2	350	13	2,140	3	300	16
1908	69,559	305,081	2,783,541	2,636	661,140	2	220	20	3,360	5	500	25
1909	51,158	130,302	1,086,104	1,740	626,511	1	125	17	2,725	8	1,520	12
1910	85,044	265,083	1,038,504	270	609,802			24	3,885	6	2,000	21
1911	126,074	403,865	2,177,378	2,857	635,726			23	4,500	7	1,800	29
1912	240,709	956,985	1,551,424	8,072	818,162	7	750	23	3,725	16	2,550	43
1913	149,619	384,820	3,292,361	10,156	686,268	5	550	17	2,725	15	3,000	42
1914	318,302	691,852	1,906,840	10,114	1,304,877			18	2,960	7	1,225	61
1915	112,491	552,372	4,240,608	11,974	768,068			26	4,120	15	2,000	63
1916	433,184	895,022	5,244,240	8,766	679,561			25	3,650	11	600	76
1917	212,296	761,231	7,599,403	9,902	712,770			20	3,300	10	1,500	97
1918	297,600	1,404,549	4,304,377	19,478	827,768	1	75	40	6,725	100	5,643	107
1919	273,775	1,170,656	2,036,515	11,786	822,679	3	250	44	8,850	5	500	115
1920	216,843	1,047,192	2,156,358	6,639	608,953	3	175	60	12,430	25	2,500	114
1921	134,143	221,488	492,279	4,196	271,138	3	450	21	2,450			17
1922	146,450	352,579	1,756,511	2,830	425,725	2	150	28	3,780	20	2,000	29
1923	114,227	380,207	3,249,692	1,772	518,006	5	850	56	9,261	20	1,331	61
1924	148,170	708,089	2,200,287	3,824	552,789	4	600	59	11,328	13	1,510	54
1925	118,402	704,978	1,296,186	3,992	525,391			48	8,960	9	900	35
1926	86,300	710,912	3,134,172	1,271	523,110			48	8,235	10	1,400	44
1927	203,331	486,117	2,447,409	45,610	345,635			64	12,675	23	1,705	52
By lines (included in above):												
1918	101			480								
1921				316								
1922				1,064								
1923				58								
1926	218			639								
1927	98,459			43,086								

[1] Statistice used in this table for the years 1889, 1890, and 1891 were obtained by taking the pack reported by Moser (1902) and multiplying the number of cases by 10, that being the number of red salmon from this district required to pack a case of forty-eight 1-pound cans, according to Moser's calculations.
[2] Data taken from reports of treasury agents.

NOTE.—No catches were reported in the years omitted from any division of this table.

Table 2 gives by localities the catch of salmon in the Icy Strait district. Of the outside localities, three are streams of the mainland between Cape Spencer and Cape Fairweather, the most western of which is Lituya Bay. This bay has produced a few thousand salmon, mostly reds, for several years, but never more than 8,000 except in 1919 when the surprising catch of 79,511 reds and 196 kings was reported. The Icy Point stream is unimportant and apparently was fished only in 1914 and 1915, yet in the latter year 1,529 kings were reported. This catch is, however, open to question as there is certainly no stream at Icy Point which under the most favorable conditions would provide a king-salmon run of that magnitude. It is also inconceivable that these fish were taken in ocean fishing from runs to more

distant places. The only explanation seems to be that an error was made in designating the locality.

The easternmost locality on the outside coast of the mainland is Dixon Harbor. It was fished irregularly from 1908 to 1924; all species of salmon were caught in some years but in no case did the total catch in any season exceed 6,000 fish. The runs, small as they were, became commercially valueless in a few years, and the harbor was abandoned, or if catches were made after 1924 they were reported as coming from other localities.

Three small streams on the western slope of Yakobi Island have been fair producers of red salmon, and have been fished regularly since the establishment of a cannery on Dundas Bay. They are tributary to Hoktaheen Cove, Surge Bay, and Takanis Bay. Hoktaheen Cove is the least important as the catch there fell from the relatively high levels maintained prior to 1910 to very low levels in recent years while in 3 years no salmon were reported from the cove. The catch has now declined almost to the vanishing point, a sure indication of depletion. Takanis Bay appears to have been fished each season from 1905 to 1927, except 1921. It produced mostly red salmon, though a few thousand cohos, chums, and pinks also were taken there. The catches have fluctuated noticeably but without indications of periodicity, except as to pinks which were more abundant in the odd years from 1913 to 1923, inclusive. Thereafter, pinks were taken in larger numbers in the even years. In respect of red salmon, the fluctuations in catch are peculiar, being high and low in alternate years from 1907 to 1915, with the peaks of production occurring in the even years. The downward movement continued however in 1916, and in the next few years, or until 1921, the better catches were made in the odd years, a complete reversal of the earlier record. The catch of 1922 was 1,334 reds, the smallest recorded up to that time, but it was followed in 1923 and 1924 by progressively larger catches. This marked the beginning of another period in which the even years took the lead in production. Nothing is known of the age of the red salmon of Takanis Bay. No scales have been studied and the record of the catch gives no indication of the sort of periodicity that would indicate their probable age. The trend of the catch was slightly downward to 1920 but since then it has apparently recovered, notwithstanding the extremely small catch in 1927. The significance of this apparent recovery is not, however, at all clear and it is not improbable that within the next few years the direction of the trend will again be downward.

Surge Bay is the most productive red-salmon locality on Yakobi Island. Omitting 1921, when it was not fished, the catch fell below 10,000 only once—in 1913. There were three peaks in the production of red salmon, the first and highest occurring in 1907 and 1908, the second in 1915, and the third in 1924. Though no catch was reported in 1921, it is probable that the run was small and that the actual abundance was not above the average of the years immediately preceding. Since no fishing was done in 1921 it may be assumed that the escapement of fish to the spawning grounds was larger than usual—if, indeed, the run was approximately the same as in the preceding years. It is possible that the increased production from 1924 to 1926 was the result of this. Unfortunately the routine observations on the spawning grounds which are now a feature of the work of the Bureau of Fisheries were not being made at this early date or we might now be in possession of some very valuable information as to the results to be expected from such an increased escapement as presumably took place in 1920. This bay produces all species of

salmon, but in all the years of its productivity, the percentage of reds in the total catch has ranged from 63 to 100. It is a seine fishery, exploited almost entirely by Indians who have fished with little or no supervision or legal restraint as officers on patrol duty visited the bay infrequently; yet it still produces red salmon in numbers comparable to the catches obtained in the early years of its exploitation, and under far more effective and better enforced laws and regulations than ever before imposed.

Lisianski Inlet and Lisianski Strait form the northwest coast of Chicagof Island and separate it from Yakobi Island. Stag Bay is an arm of Lisianski Strait. According to available data, fishing began in the strait in 1905 and was continued each year through 1920. Apparently no fishing was conducted here in 1921 and 1922, and although it was resumed in 1923, no catches have been reported therefrom since 1924. Fair catches of pink salmon were made regularly in this locality; and in a few years, during the period of intensive fishing on account of the World War, unusually good catches of cohos, chums, and reds were also made. The catches of these three species, however, were insignificant in the first 10 years of fishing and have been unimportant since 1920. Catches of pinks, chums, and reds in Lisianski Inlet, which includes a small catch at Miner Island in 1927, show less violent fluctuations than do those in the strait. Coho catches were more variable, and kings were taken quite irregularly. The presence of the latter species in both Lisianski Strait and Inlet is presumably an indication that these waters are traversed by salmon entering Cross Sound, as it is not likely that the small streams tributary to the strait and inlet support runs of even a few hundred kings. In the same way it is possible to account for the better catches of other species, especially reds, in some years, as bearing a relation to the number of salmon using this passage as a migration route. Had there been any stream in Lisianski Inlet which would produce as many as 19,000 red salmon in a season (which was the approximate catch there in 1916), that fact would certainly have been discovered a decade earlier and development of the locality would have been contemporaneous with that of Surge Bay and other streams in the same region. It is quite probable that traps were used here and intercepted the runs of migrating salmon although there are no definite records to this effect. Salmon were taken from Stag Bay in each season from 1923 to 1927, and all species were included in the catch, with pinks predominating.

Soapstone Harbor is a small indentation on the north end of Yakobi Island. It was fished occasionally from 1908 to 1919, and regularly from 1924 to 1927. All species of salmon, except kings, have been taken there but the catch was invariably small, and possibly included fish from the main runs into Cross Sound.

There are 21 localities in the Cross Sound section of the Icy Strait district which are treated independently in table 2. They include 17 other localities in which small catches were made, or which had been fished but one season. These places will be referred to in the discussion of data for the localities with which they were merged.

Cape Spencer, on the north side of the entrance to Cross Sound, is shown as a separate locality because several thousand red salmon were reported as captured at that point in the 4 years from 1915 to 1919, excluding 1916 in which no catch was reported. The catch in 1920 was small and again in 1921 no catch was reported. In 1922, fishing was resumed and continued through 1927 but with much smaller returns. The catch of other species shows the same peculiarity as was noted in respect to reds, the earlier years being more productive than the later years. One of the outstanding irregularities in the Cape Spencer data, if indeed all of the data are not irregular, is the catch of 1,569 king salmon in 1919, reported by the North-

western Fisheries Co. Not even a closely similar catch of kings was ever made before or has since been made in that locality, and there is no stream near Cape Spencer that could be expected to produce that number of king salmon. No satisfactory explanation of this unusual catch can be given; it may possibly have been made by trollers operating in the vicinity of Cape Spencer, or the name of the locality may have been incorrectly reported. The most reasonable explanation, however, seems to be that the catch came from Alsek River. Various other irregularities in the data from this locality make it apparent that they are not to be considered as reliable.

Taylor Bay, the first indentation of the mainland east of Cape Spencer, produces chiefly red salmon. It is a gill-net fishery, due to the roily condition of the water which is caused by the drainage from Brady Glacier. Available records indicate that fishing began here in 1904 with a catch of 20,000 red salmon and continued with few interruptions during the period covered by this report. The data are peculiar on account of their extreme irregularity, which is unusual in a record that extends over as long a period of time as does this. It seems very unlikely that the great fluctuations in catch reflect abundance, and one can only conclude that the record is so faulty that any attempt at analysis would be useless.

Port Althorp indents the north shore of Chichagof Island a few miles east of Lisianski Inlet. A saltery was located there in 1893 and packed 600 barrels of salmon, presumably reds. No further operations in this locality were reported until 1905. In that year a few thousand pinks were caught. The bay was not fished again until 1908, nor does it appear that any salmon were taken from it in 1911 and 1912. The record is unbroken from 1913 to 1927, large catches being reported in some of the earlier years of this period. A cannery was built on the west shore of Port Althorp in 1918, but the catches from that year on never closely approached the yield in the years just preceding except in 1921 when 72,873 red salmon were reported as coming from those waters—much the largest catch of reds ever recorded. More salmon were taken in Port Althorp in 1916 than in any other year, the peak of production affecting cohos, chums, and pinks. The banner year for reds, as just noted, came 5 years later, while the largest take of kings was recorded in 1917. The "big years" at Port Althorp were 1915, 1916, and 1917. In 1916, a catch of 733,429 salmon was reported from this bay. After 1918, good catches were made but they averaged far below the levels of the preceding decade. There are no apparent cycles in the catches of any species, even the 2-year cycle in the runs of pinks, as observed in some localities in central Alaska, being lacking. These conclusions are of course based upon the assumption that the data are reliable and that all salmon shown as coming from Port Althorp were actually caught in that bay and not in Cross Sound or some other outside locality. The catches of kings from 1916 to 1920 were probably made by trollers operating in Cross Sound or nearby ocean waters and were packed or mild-cured at Port Althorp. Catches made at Georges Island in 1926 were merged with Port Althorp catches for that year.

Cross Sound properly includes Three Hill Island, the Inian Islands, Lemesurier Island, and some localities on the mainland shore between Cape Spencer and Point Carolus, several of which are merely trap locations. Data for these several localities are given in table 2 under the proper names of all localities which were considered sufficiently important to warrant separate treatment. Several other localities were fished occasionally; but the catches were usually small, evidently representing a single seine haul or the results of trap fishing for one season only. These catches were combined with those reported from Cross Sound and cover the following places: Salt

Bay in 1912; Canoe Point in 1913; Deer Bay in 1917; Garden Point in 1917, 1918, and 1920; Grindall Point in 1919; Salmon Bay in 1923; Salmon Beach in 1924; Salt Chuck in 1925; Calamity Point in 1926; and Middle Pass, Salmon Creek, and Pile Trap Cove in 1927. A catch reported from Earl Cove in 1927 was added to the Inian Islands total for that year, and catches from North Passage in 1924 and 1927 were included with those reported from North Inian Passage in the respective years.

Traps were used in this field at points on the shores along which passed the schools of salmon destined to more easterly waters. Prominent points or capes at breaks in the shore line were preferred as trap locations if the tidal currents were favorable. Good catches were commonly made at such places by traps. Purse seines were also fairly effective at some points.

The available data show that fishing began in Cross Sound in 1911 with a fair catch of coho, pink, and red salmon and that catches were made each season except 1922, through 1927. In the earlier years of this period the catch of reds held a moderately even level; but after 1916 striking irregularities were observed, probably due to more exactness in the allocation of catches rather than to irregularities of the runs. Fluctuations in the catch of all species were extremely irregular in this latter period and apparently bear no relation to the size of the runs in any year as indicated by the catches in other and nearby districts. This is exactly what might be expected in a locality of this kind where the catches are taken from migrating fish whose route of travel may possibly change slightly from year to year under the influence of various environmental conditions.

In 1927, a trap, located on the shore of Three Hill Island in Cross Sound, made a catch of 96,271 salmon. Other traps placed along the shores of Inian Islands in that and earlier years evidently have tapped the main runs of salmon to Icy Strait and beyond as the islands have no local runs worth mentioning. It might appear from the catches reported as coming from Inian Cove that runs of considerable magnitude originated in that locality, but such is very certainly not a fact. These catches were made by traps, at the entrance of the cove, from passing schools of salmon. Salmon coming into Cross Sound from the ocean use the several Inian passages in their eastward movement but the main body of fish probably follows the north passage. After passing the Inian Islands, the runs swing to the southward and strike the north shore of Chichagof Island from Gull Cove to Point Adolphus.

Catches of salmon in the Inian Islands section have been uniformly good and in some years exceptionally large catches were made, particularly of pinks. At this point the runs are composed of salmon bound for many localities to the eastward, and the volume of the runs has been reduced, up to this point, only by the deflection of fish into Taylor Bay on the north and Port Althorp on the south. After passing this group of islands the fish bound for Dundas Bay and Idaho Inlet leave the main stream of migration and this further reduces the runs.

Dundas Bay is an irregularly shaped indentation of the mainland north of the Inian Islands. On the eastern side of the bay at the mouth of Dundas River is one of the oldest red-salmon fisheries in the Icy Strait district. No doubt its exploitation began with the establishment of the cannery at Bartlett Cove, but data are not available showing the catch, if any, before 1904. Beginning with that year, this bay has been a steady producer of salmon for 24 years, all species being taken from its waters. Its importance, however, lies particularly in the red-salmon catches and in the fairly constant production of pinks and chums since 1916. Traps were located between the mouth of the river and Dundas Point on the eastern side of the entrance

to the bay; traps were also operated at the point and caught all species of salmon some of which may have been Dundas River fish. Salmon Beach is in the same general locality; small catches in a few years have been taken at that place chiefly by seines. In 1926 and 1927, Dundas Bay was closed to all fishing for salmon north of 58° 21′ north latitude, except with gill nets.

Idaho Inlet indents the north shore of Chichagof Island just south of the Inian Islands. It has little importance as a fishing locality, although all species have been taken there. In 1918 a catch of 1,099 king salmon was reported in the inlet by one company, but this was unquestionably an error as there is little probability that this number of kings ever entered the inlet. Two other companies fishing in the same waters caught no kings at all. In two years, 1917 and 1926, catches were reported from Shaw Island, at the west entrance to Idaho Inlet, representing the results of trap fishing at that point. To what extent these catches were composed of Idaho Inlet fish cannot be determined, but it is not likely that there was such a definite cleavage of runs at this island as to eliminate all except inlet fish. Inasmuch as the streams of the inlet are not known to be particularly productive it is entirely probable that fish from the Icy Strait run were taken at Shaw Island.

Lemesurier Island lies in the center of the eastern end of Cross Sound. Its western and northern shores have been used as fishing grounds for traps in several years with fair results due to the fact that the runs of salmon touch these shores in their eastward migration.

Glacier Bay, a deep indentation of the mainland, nearly 100 miles in length is the outlet of drainage from a wide field of active glaciers. During the annual period of greatest activity, icebergs and smaller blocks of ice are swept out of the bay into Icy Strait and become a real menace to the navigation of vessels passing through those waters. They have often caused damage to fishing by breaking down traps and wrecking seines operated in Cross Sound and Icy Strait. The bay, however, produces few salmon although it has many tributaries which long ago lost their glacial characteristics and should now afford some areas for spawning grounds. Salmon have been reported from three localities within the bay—Bartlett Cove, Berg Bay, and James Bay, but at none of them has the catch of any species except reds exceeded 6,000 in any year. The production of reds has been appreciably higher.

As stated elsewhere in this review, a cannery was erected at Bartlett Cove in 1889. The pack that year consisted of 4,300 cases of salmon, probably all reds, the first to be canned in the Icy Strait district. This plant was operated three seasons, 1889 to 1891, and was then closed and eventually dismantled. About the time it closed, a saltery was opened at the cove and packed a few hundred barrels of salmon. Data are not now available showing the source of the salmon thus utilized, but it is highly probable that the greater part of the catch came from the stream at Bartlett Cove. It was due to the presence of redfish in this stream that the cannnery and saltery were located there, it being the custom at that time to establish the packing plant at the most important fishing ground. Catch records for those years are not known now. The earliest recorded catch at Bartlett Cove was made in 1905. From that year to 1918, inclusive, the catch of red salmon ranged from 7,514 to 21,191; from 1919 to 1924, it was less than 3,000 each year catches were reported, there being no record of catches in either 1921 or 1922. These diminished catches are unmistakable signs of depletion as no regulation or restriction of fishing influenced the catch during that period.

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The situation at James Bay closely parallels the condition at Bartlett Cove, the catch falling off markedly after 1918. Catches at Berg Bay were also insignificant. In view of the evident depletion of all Glacier Bay salmon runs, as indicated by the reported catches, the bay was closed in 1925 to all commercial fishing for salmon.

On the north shore of Chichagof Island at the eastern entrance to Idaho Inlet is a small bight known as Gull Cove. Into it flows a stream of unknown importance as a producer of salmon; traps have been operated on both sides of the cove, but the one on the north shore caught practically all the salmon that were reported as coming from this locality. The record shows catches for 6 years, 1913, 1914, and from 1924 to 1927. In the last 2 years, large numbers of pinks were caught and several thousand cohos, chums, and reds were also taken. Perhaps not one of these catches was made directly in the cove though the stream presumably supports something of a run of salmon. The presence of considerable numbers of kings and reds in the catches is, however, positive proof that the Gull Cove catches were not taken wholly or even to any large extent from local runs. Salmon passing eastward evidently touch the shore at this point before swinging down the coast toward Mud Bay, and are captured while passing the point where the trap is located. In some respects the data for Mud Bay are similar to those for Gull Cove. The stream at Mud Bay is not regarded as an important salmon stream; and it is certainly not a red-salmon stream, so the catch of 14,282 red salmon recorded for that locality in 1920 in that bay can only be explained by the operation of traps which drew on the main run toward more eastern waters.

The Icy Strait section of the Icy Strait district covers the waters east of a line from Point Adolphus to Point Gustavus to the end of the district at Point Couverden and Point Augusta. The data presented in the table include the catches from 16 major and 10 minor localities and parts of certain catches from other districts for which no segregation was made by the packers. The minor localities are given here, with the year in which the catches were reported from each one, as follows: Icy Passage in 1914 and 1923; Gedney Channel in 1917; Icy Strait and Cross Sound in 1917, 1918, 1919, and 1923; Eagle Bluff and Neck Point in 1918; Soapstone Island in 1920; Flynn Cove in 1924; Riverside in 1926; and Eagle Cove and North Island in 1927. The catches which were divided were reported under the following locality designations: "Icy Strait, Chatham Strait, Peril Strait and Bays" from 1905 to 1919 inclusive; "Icy and Chatham Straits" from 1905 to 1921, inclusive; "Chatham, Peril, and Icy Straits and Bays, and Karheen" in 1921 and 1922; "Icy Strait and Frederick Sound" from 1918 to 1921, inclusive; "Icy Strait and Lynn Canal" in 1919; and "Icy Strait and Stephens Passage" in 1917 and 1919. No uniform rule could be applied in making a division of catches reported under these headings; it was found desirable to make allocations on the basis of local knowledge of the field and scope of operations of each packing company rather than to make an arbitrary division and to assign any constant fraction of the entire catch in each year to the localities involved. Such a procedure is quite unsatisfactory in many ways, particularly when seen from an orthodox statistical viewpoint; however, the desire is to present as complete and accurate picture of the history of these fisheries as is possible with the available information and it has seemed better to attempt such an allocation rather than to throw all catches in which two or more localities have been combined into the unallocated section, which is the only alternative. It is believed that on the whole the general picture will be more complete and significant if these allocations are made on the basis of such information as to local conditions as is now available and which is not likely to improve with the passage of time.

The north shore of Chichagof Island from Point Adolphus to Point Augusta constitutes one of the more important fishing grounds of the Icy Strait section and one in which the operations are confined chiefly to traps. Large catches were also made by traps located along the southern shore of Pleasant Island and on Porpoise Island. Traps were also located along the north, or mainland, shore between Point Gustavus and Excursion Inlet and produced thousands of salmon; but the most fruitful section in the entire Icy Strait district was the mainland shore from Excursion Inlet to Point Couverden, a distance of approximately 20 miles, along which nearly 50 traps were driven in a single season. The catch along that shore has been consistently high, running into the hundreds of thousands and millions of salmon, and easily accounting for 50 percent of the entire catch in the Icy Strait district. At no other section of the coast between Cape Spencer and Point Couverden do salmon strike in such volume as on the Excursion Inlet shore. Several small streams enter the strait along that coast, each of which has its run of salmon, but it is certain that they do not produce the large runs which invariably follow that shore. If the runs were local, the traps nearest to Point Couverden would presumably catch fewer fish than those nearer Excursion Inlet, but that is not the case, as the traps near the end of the peninsula make large catches, although the streams are small and unimportant in that section. The greater part of the runs which are intercepted here is obviously moving on to still more distant streams.

Groundhog Bay is a shallow indentation on the Excursion Inlet shore without significance as a separate locality. It is a name given to a trap location by one company and is not an accepted geographic name, but is used in this review because it serves to identify the place at which certain catches of salmon were made. The more exact the information is in respect to localities the more useful and important it becomes in the consideration of subsequent data covering the same locality.

Division Point is also the name of a trap location between Excursion Inlet and Point Gustavus. Catches were recorded there in 1926 and 1927, and it is probable that catches were made in earlier years but were reported under some more general locality name, probably Icy Strait.

On the south side of Icy Strait, or the north shore of Chichagof Island, are several localities—Point Adolphus, Eagle Point, Point Sophia, Pinta Cove, Spasskaia Harbor, and Whitestone Harbor—at each of which large catches of salmon have been made in some years, showing that a rather heavy migration of salmon follows this shore, not all of which is destined to enter local streams. The fairly high average returns at the several places indicates that a considerable body of salmon reaches the eastern end of Icy Strait, notwithstanding the many traps and nets which obstructed the way and the fact that many salmon traversing Icy Strait enter local spawning streams. In addition to the fish leaving this migration route to enter the streams debouching directly into the strait, Port Frederick on the south and Excursion Inlet on the north draw their respective runs from the main body of eastward-bound salmon.

Port Frederick is the largest bay which indents the north shore of Chichagof Island; its tributary streams provide spawning grounds for pink and chum salmon chiefly, although small catches of other species have been recorded in nearly every year since 1911. The data for this bay include catches made at Humpey Creek in 1917, 1919, and 1920 and from Game Creek, Howard Creek, and Neka Bay in 1918. Salmon catches were first reported from Port Frederick in 1905, but no concentrated fishing effort was made there until 1911, when a catch of 205,801 pinks

was reported, a record which has not since been equaled. The catch of both pinks and chums fluctuated widely, pinks reaching high peaks in 1911, 1917, and 1923, while the catch of chums was especially high in 1912 and again in 1924. In two cases the pink-salmon peaks followed a year in which no catch was recorded, and in the other case it followed a year in which the catch was less than 10,000. The evidence indicates, although not too clearly, that the pinks of this bay were running more heavily on the odd years during this period. After 1924 the catch was doubtless affected by the closure of the bay east of a line from Inner Point Sophia to Game Point and the prohibition of fishing in the head of the bay.

Pleasant Island, Porpoise Islands, and The Sisters are productive areas in the Icy Strait district, affording favorable locations for the operation of traps. The catches at these points came from the runs of migrating salmon which were destined to the tributaries of Chatham Strait and Lynn Canal, the greater part of the reds, kings, and cohos moving northward, while the pinks and chums sought primarily the streams to the southward. These and other facts respecting the migrations of salmon in southeastern Alaska have been shown in a series of reports dealing with tagging experiments in this district.[9]

Excursion Inlet, indenting the mainland on the north side of Icy Strait, is primarily a producer of chums, although it would appear from the data presented in the table that it also has produced other species in considerable numbers, the figures for 1920 being especially in point. However, these catches were probably made along the shore south of the inlet from the runs of salmon passing to the eastward, and should be included with the regular Icy Strait catches. They were reported, however, under the name of Excursion Inlet as being the easiest means of identification of location.

The section of the table headed "Unallocated", includes all catches reported from the Icy Strait district but without reference to particular localities. It obviously includes, as might well be expected, a very large percentage of the total number of fish taken in the district, and it is not unlikely that catches are included which were actually taken outside the area commonly known as Icy Strait. Thus fish taken in Cross Sound and elsewhere were frequently reported as coming from Icy Strait and there is no way in which these errors may now be rectified. Obviously it is pointless to give any consideration to the fluctuations in the unallocated catch. There follows a discussion of the total catch in the Icy Strait district.

The catches in Icy Strait (see fig. 13) have been notably affected by the various economic causes which have been mentioned in the introduction (p. 438) and cannot always be accepted as indices of the relative abundance of salmon in these waters. For example, the catch of chums in 1912 was much greater than in 1911, but this does not necessarily mean that the actual abundance was greater. The true explanation is, doubtless, that there was an increased demand for this species in 1912 resulting in a greater fishing effort and a greater catch. In a general way it appears to be true that, in years in which a small catch of pink salmon was made, the catch of chums was increased. This is, however, particularly true of the period during which the development of the industry, so far as the packing of pinks and chums was concerned, was

[9] Salmon-tagging Experiments in Alaska, 1924 and 1925, by Willis H. Rich. Bulletin U.S. Bureau of Fisheries, vol. XLII, 1926 (1926), pp. 109–146, Washington.

Ibid.—1926. By Willis H. Rich and Arnie J. Suomela. Bulletin, U.S. Bureau of Fisheries, vol. XLIII, 1927 (1927), pp. 71–104, Washington.

Ibid.—1927 and 1928. By Willis H. Rich and Frederick G. Morton. Bulletin U.S. Bureau of Fisheries, vol. XLV, 1929 (1929), pp. 1–23, Washington.

Ibid.—1930. By Willis H. Rich. Bulletin U.S. Bureau of Fisheries, vol. XLVII, 1931 (1932). pp. 399–406, Washington.

going on. During this period there was evidently a supply of chums greater than any demand that was then made so that in years in which pinks were scarce it was easy to increase the pack of chums. There is considerable evidence of such an interplay of factors, both biological and economic, affecting the catches of these species. The

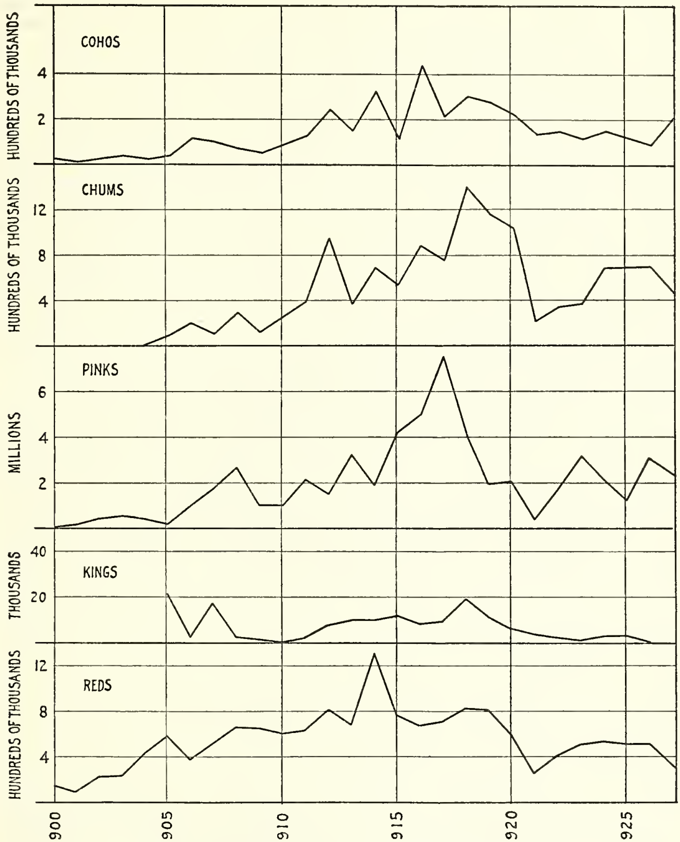

FIGURE 13.—Catch of salmon in the Icy Strait district, 1900 to 1927.

increased demand for chums in 1912 may be ascribed to a relative scarcity of pinks since the catch of pinks in that year was only a little over 1½ million as compared with over 2 million in 1911 and over 3¼ million in 1913. The catch of chums dropped again in 1913 presumably due to this relative abundance of pinks and the low prices which then prevailed for the canned product.

In 1914 again, pinks were not so plentiful and prices were higher, consequently more chums and cohos were used. This happened also to be the best year ever known for reds on Icy Strait. The next year (1915) again brought a heavy run of pinks which enabled canneries to complete their packs before the late run of chums appeared, although the catch of this species was not greatly lowered. Conditions apparently remained about the same in 1916. In 1917 owing, no doubt, to the high prices for canned salmon then prevailing, production was again high, and although the main run of salmon was late in entering Icy Strait, the district produced more pinks that year than ever before or since. Large catches were also made in 1918, especially of chums. In the next 2 years, the catches were smaller and what appear to be the first signs of overfishing became evident in the Icy Strait district. These relatively poor years were followed by a material slackening of operations in 1921, due to economic conditions and the large surplus of pink and chum canned salmon remaining from the packs of 1919 and 1920. Some recovery was apparent in 1922; but even in that year several canneries remained closed while those that did operate limited their packs. At that time some concern was felt over the probable permanent decline of these fisheries. In 1923, however, the catch of pinks improved materially but there was no marked change noted in the abundance of the other species. During the remaining 4 years covered by these records the catch of all species was moderate due in part at least to the conservation measures placed on the fishery in 1924 and subsequently, although it seems probable that depletion may also have been a factor in reducing the catches to a level well below that maintained from 1915 to 1920.

The catch of red salmon showed a rather steady development until it reached a climax in 1914; since then the fishery has declined by two abrupt drops, separated by a few years of moderately steady production. After the sharp falling off from 1918 to 1921, recovery has been slight, being affected somewhat by stricter regulation of commercial fishing. Yet there is little doubt that this fishery shows depletion and that the trend of the catch has been downward since 1914.

Apparently the runs of pink salmon in Icy Strait were not exploited before 1900 and no serious attempt to fish them was made until 1906. It was necessary to establish a market for pink salmon before the fisheries could be developed to their maximum productivity and to create a demand for them before the full use of the available supply could be undertaken. The growth of the industry was gradual through the next 8 years, but from 1915 to 1919 these fisheries, under the stimulus of the World War, were exploited so relentlessly that unprecedented catches were made in the strait until the maximum of over seven and a half million was reached in 1917. Production then fell gradually, apparently chiefly from economic reasons, until the catch of 1921 was less than half a million. This decline was immediately followed by larger catches in the next 6 years which were equal to or above pre-war levels. Although the catch in 1925 might indicate a comparatively poor run of pinks in that year, it was recorded by Bower (loc. cit., 1925, p. 103) that the escapement of salmon into the streams of southeastern Alaska was the best that had been observed in years. The catch in 1924 declined probably for no other reason than that all fishing was prohibited for 20 days in August; in 1925 a similar closed period was enforced and additional restrictions were applied by increasing the distance interval between traps to 1½ miles. This affected fishing in Icy Strait along the shore from Excursion Inlet to Point Couverden more than elsewhere, due to the greater number of traps in that section, but the catch at points unaffected by these regulations raised the total to a level comparable to that of other years and without further change in the regulations

the catch in 1927 in Icy Strait was nearly double that of 1925. However, the catch in 1926, under possibly more stringent regulations, was nearly half again as great as that of 1924. It is of particular interest in this connection to note that while the catch of pinks was reduced in some sections of the strait by the imposition of restrictions on fishing, it was sufficient in other sections to bring the total catch to approximately normal levels and leave no evidence of depletion in this large district.

The catch of chum salmon in the Icy Strait district increased quite steadily from 1904, when the first catch was recorded, to 1918, in which year the catch was nearly one and a half million. The production from 1916 to 1920, inclusive, was fairly steady, averaging over a million fish annually. The break in 1921 resulted in the reduction of the catch to less than half a million fish and in no subsequent year up to 1927 did the catch greatly exceed 700,000. Some of the causes of fluctuations in the catch of chums have already been discussed in connection with the treatment of the catches of pinks. The reduced catch since 1920 is not to be regarded as conclusive evidence of diminished runs since, as has been pointed out above, the chum runs are not ordinarily fished intensively. It seems probable that the abundance in this district has not changed materially since the earlier years.

Cohos are taken in fairly large numbers in Icy Strait, but run much later in the year than do the other species and therefore the catches do not necessarily represent the full value of this fishery as canneries were frequently closed before the runs attained their maximum volume. As measured by the reported catches, the coho fishery reached its highest development in 1916. Since then the catches have been gradually smaller in Icy Strait though cohos were probably just as abundant in 1927 as ever before. The productivity of this locality has probably been somewhat affected by the regulations establishing a closed season during the early part of the coho run in order to protect the end of the pink salmon run.

The king salmon catch in Icy Strait, while never large, was maintained at a fairly constant level for many years down to 1920, but between that date and 1927 it held a notably lower level, although it is impossible to assign a definite cause for this. In 1927, however, the reported catch reached the unprecedented figure of over 45,000 most of which were reported as having been taken by lines in Icy Strait. The streams in the Icy Strait section are small; and so far as is known few, if any, kings are native to them. It is quite certain that the king salmon runs are merely migratory fish bound possibly for the Chilkat and Taku Rivers, or even native to the large rivers farther south, such as the Columbia, which are known to frequent the feeding grounds off the coast of southeastern Alaska.

In summarizing the data for the entire Icy Strait district, certain localities show positive evidence of depleted runs of salmon, especially the bays in the western part of the district; but so far as the runs passing through Cross Sound and Icy Strait are concerned there is little indication of a failing supply of salmon. Although the catches were smaller at the end of the period here reviewed, they were not far below the level of production that might reasonably be expected to be maintained under normal fishing. The intensive fishing, as carried on for a few years, would undoubtedly have worked havoc with the Icy Strait supply of salmon, but fortunately this period was followed by a few years of materially lessened activity permitting reestablishment of such runs as may have been depleted. The only exception is the reduction in the catches of red salmon which can be ascribed in part to depletion in certain local areas and in part to changes in the laws and regulations affecting the fisheries. The

smaller catch in 1927 is not necessarily indication of extreme depletion since the escapement was said to be good.

In general it may be said that there was a marked upward trend of the red salmon catches until 1914, of cohos until 1916, and of pinks until 1917, but since these years the trend has fallen abruptly, its decline being accentuated by the economic depression of 1921. Recovery has been less abrupt than the decline, yet the gains in recent years have been substantial and indicate an eventual rebuilding of the fishery to its original strength.

LYNN CANAL

The Lynn Canal district covers all territorial waters north of a line from Point Couverden eastward to the point at the south side of the entrance to Funter Bay, thence along the watershed of Mansfield Peninsula, northward to Point Retreat, thence to the north end of Shelter Island, and thence to a point on the mainland shore 2 miles north of the mouth of Eagle River. The boundaries of the district are shown in figure 14.

Lynn Canal is a narrow body of water extending northward from the east end of Icy Strait for a distance of approximately 90 miles. It has two important tributaries—Chilkat River and Chilkoot River—both of which enter their respective inlets near the head of the canal. Other localities of the district are of slight importance, except possibly the Mansfield Peninsula shore north of Funter Bay which has been a favored locality for traps, intercepting, as they did, not only the runs of salmon to the Chilkat and Chilkoot Rivers but those to Taku River, a tributary of Stephens Passage, 50 miles southeasterly from Point Retreat.

The history of the Lynn Canal fisheries dates from the opening of a salmon cannery on Chilkat Inlet in 1883. In a few years four canneries were operating in the district, and the runs of salmon at both Chilkat and Chilkoot Inlets were exploited simultaneously. As the industry developed, the field of operations was extended until salmon caught in Icy Strait were being packed at the Chilkat canneries, and fish from Lynn Canal were being canned in the packing plants of Icy Strait, Stephens Passage, and Chatham Strait. Fishing in Chilkat Inlet was done largely by drift gill-netting, but large catches were also made by Indians fishing with gaffs in both the Chilkat and Chilkoot Rivers. In time, traps were located at points along the east shore of the canal and all tributary bays were prospected. Beach seining was tried at the mouth of Chilkoot River, due to its clearer water being less affected by glacial drainage than Chilkat River, but with little success, as the beaches were too rough. Gaffing in the river and set nets in both the river and the lake in the hands of natives probably accounted for the greater part of the salmon taken here during most of the earlier years.

The statistical data here presented were derived from three sources. For the first 11 years the catches were determined by using the pack figures reported by Moser (1902) and assuming 11 fish per case. There is no means of ascertaining the number of salmon of each species used commercially in these years, as Moser's figures give only the total pack of all species; but the entire catch has been considered to have been red salmon, though it is not at all improbable that both cohos and kings were included. If so, however, they certainly constituted only a very minor part of the pack. Moser (1899, p. 126) says, in writing about Taku River, that "As soon as the ice breaks up in the river (usually about May 25) the fishing for king salmon commences and all that are packed at Pyramid Harbor are taken in the Taku, except

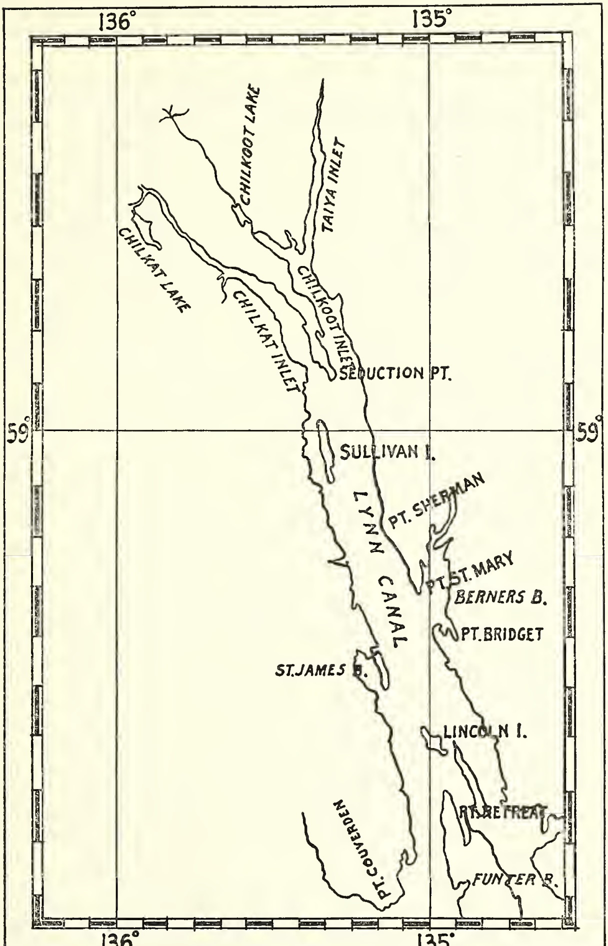

FIGURE 14.—Map of the Lynn Canal district.

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a few stragglers that appear around the Chilkat very early in the season, which can hardly be called a run." (Pyramid Harbor is a part of Chilkat Inlet.) While this condition was no doubt true at the time of Moser's investigations, in more recent years king salmon have been taken at various points on Lynn Canal which could hardly have come from the Taku runs.

From 1894 to 1903, a period of 10 years, the reports of the treasury agents in Alaska were drawn upon for catch records, use being made of their figures for each species. Their reports show, however, only the locality where the salmon were packed and not the actual source of the catch. It is unsatisfactory, of course, to have to allocate these catches on such a basis, but there is no other alternative; and it is probable that errors resulting from this are at least partially compensating. In the case of these early years no attempt has been made to allocate catches to smaller geographical units than the districts, so that the early records are always to be found under the "Unallocated" section of the tables for the respective districts.

In the later period, 1904 to 1927, the catch statistics were taken as usual from annual statements required of the packers. Where catches were reported from localities such as "Icy Strait and Lynn Canal", "Lynn Canal and Stephens Passage", "Chatham Strait and Lynn Canal", and the like, it was necessary as before to make an arbitrary division of such catches, relying largely upon personal knowledge of local conditions and the field of operation of the several companies engaged in fishing, together with a general understanding of the relative productivity of the various localities. One company may take 90 percent of its catch from Stephens Passage and 10 percent from Lynn Canal, whereas another packer may take 75 percent of his catch from Lynn Canal and 25 percent from Icy Strait. For such reasons no fixed rule could be followed in the division of these catches; each case had to be decided on its own merits. In other instances, where small catches were reported from places within larger or more important localities, they have not been kept separate but were combined with the catches from the larger fields. Again, in cases where localities were incorrectly named and the names used were obviously intended for something else, the necessary corrections were made without hesitation. As far as possible, the names of waters, points, and islands, as adopted by the United States Coast and Geodetic Survey, have been used in this report, but where this course could not be followed, the names used by the fishermen or packing companies have been accepted without further question. Where two names were given to a single locality, or where the proximity of localities suggested a consolidation of catches at such points, preference was given to the better known name. Localities listed in the table are shown on the map; others are referred to in the discussion of the data.

Fishing at the Chilkat and Chilkoot Rivers was subject only to the general fisheries laws and regulations, which applied throughout Alaska, until special protection was given the runs of salmon here by prohibiting the use of all fishing appliances within 500 yards of the mouths of both rivers on and after January 1, 1919. The regulations of 1925 established a closed season from August 11 to August 31, and those of 1926 also prohibited the use of traps and purse seines in Lynn Canal north of 58° 26′ north latitude. In addition, all fishing was prohibited in Chilkat Inlet north of the south end of Kochu Island and in Chilkoot Inlet within 1,000 yards of the mouth of the river except with gill nets from September 5 to October 15 in each year. These regulations closed all the preferred fishing grounds in Chilkat and Chilkoot Inlets and directly affected the catch in those localities. In fact, no salmon have been reported as being taken in Chilkoot Inlet since 1924.

The Lynn Canal district embraces 23 localities, the identity of which has been preserved, although in some cases the catch covers but 1 year, and 24 localities whose catches have been merged with others or divided between the areas named. Table 3 shows the catch of salmon in the Lynn Canal district.

TABLE 3.—*Salmon caught and fishing appliances used in the Lynn Canal district, 1883 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Berners Bay:												
1919	398	21										
1922	6,408	5,249	11		179							
1923	553	66			5							
1924	95	4,221			512							
1925	4,747	7,720	8		564							
Bridget Cove:												
1911	600	250	250	250	1,000							
1912	1,500	900	400	200	3,000							
1913	500	1,150	2,700	150	3,000							
Bridget Point:												
1922	1,014	2,070	2,308		5,504							
Chilkat Inlet and River:												
1904	9,614	54,308		144	156,529							
1905	22,183	5,000		558	126,571							
1906	17,890	27,879		612	133,472							
1907	74	8,565		2,174	20,243							
1908		11,464		2,134	34,751							
1909		5,047			83,537							
1910				1,500	294,547							
1911	18,047	76,420		899	117,989							
1912		37,182	40	587	90,612							
1913					6,932							
1914	19,680	46,910	533	14	62,584							
1915	1,048	18,920			60,741							
1916	23,564	96,039	21		69,721							
1917	27,513	53,971		53	98,832							
1918	14,435	102,038	1,694	120	94,623							
1919	29,473	189,273		1,155	69,708							
1920	2,720	23,919	5,731	398	15,014							
1921	624	1,334			15,128							
1922	5,992	38,861	782	30	11,964							
1923	14,686	107,415	5,019		47,530							
1924	13,102	69,529	846	1,586	34,962							
1925	2,565	6,140		675	275							
1926	14,057	35,878	1,275		40,651							
1927	22,730	24,797	206		41,835							
Chilkat Island:												
1920	16,451	38,035	11,910		25,618							
1921	18,595	9,515	164	17	23,997							
Chilkoot Inlet and River:												
1904			60,000		120,000							
1906	43,376	16,513		1,155	260,174							
1907		6,606	1,547	140	74,476							
1909		5,047			83,537							
1910					68,205							
1911					41,226							
1914					90,185							
1915			2,106		98,205							
1916	1,199		751		71,703							
1917	712				64,001							
1918	6,942	2,917	1,237		28,143							
1919					14,427							
1921	1,779				28,723							
1922	1,586	3,967		197	11,710							
1923	3,491	775			16,086							
1924	1,226	5,195	1,041		23,504							
Clear Point:												
1926	575	7,351	28,558	13	5,051							
Eldred Rock:												
1922	2,883	4,041	1,878	81	11,373							
1925	620	1,380			19,750							
False Point Retreat:												
1923	269	1,116	17,807		1,585							
1924	3,076	10,383	54,268	557	13,683							
1925	6,141	32,053	113,980	67	19,288							
1926	1,334	33,222	39,155	64	18,545							
1927	550	8,340	16,847	55	3,632							
Funter Bay:												
1919	62	2,493	7,099									
1924		6,931	1,172		1							
1925	2,721	22,025	23,951		8,943							
1926	5	16,867	4,565	50	6,593							
1927	755	7,983	17,953		2,598							

TABLE 3.—*Salmon caught and fishing appliances used in the Lynn Canal District, 1883 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Hudson Bay:												
1907	2, 486	6, 983	68, 560	1, 221	31, 780							
1912	570	36, 147			463							
1913	1	288										
Kittens, The:												
1922	636	7, 712	34, 151		6, 167							
1927	2, 000	4, 500	32, 258	30	2, 000							
Lincoln Island:												
1911	289	740	1, 618		816							
1916	4, 000	500	1, 500	1, 500								
1917	82	1, 213	25, 659	6, 159	1, 245							
1918		5, 176	407		86							
Mansfield Peninsula:												
1910	16, 817	24, 169	183, 622	800	82, 131							
1911	15, 324	36, 403	175, 376		52, 408							
1912	6, 985	35, 406	50, 805	93	35, 163							
1914	16, 526	38, 752	115, 950	180	73, 948							
1922		25	25	25	300							
1923	168	1, 530	15, 600	10	1, 120							
1924	6, 396	7, 812	39, 619	12	8, 259							
1925	4, 540	31, 070	40, 137	52	30, 391							
1926	895	9, 976	35, 678	71	7, 467							
Naked Island:												
1920	5, 382	9, 892	15, 823	124	12, 608							
1921	6, 868	3, 545	48, 595		12, 148							
1924	2, 262	5, 828	221		5, 324							
1925	1, 423	8, 103	10, 422	22	7, 070							
1926	1, 000	18, 000	45, 315	23	9, 662							
Retreat, Point:												
1917	2, 254	1, 672	21, 110		2, 860							
1918	497	4, 318	42, 888		1, 656							
1920				371								
1922	920	5, 247	22, 624		9, 764							
1923	2, 196	4, 366	25, 554	4	6, 331							
1926	690	8, 825	27, 500	114	6, 322							
1927	2, 476	5, 473	25, 244	208	10, 670							
St. James Bay:												
1924		2, 724	8, 215		1							
St. Mary, Point:												
1912		8, 594			30, 757							
1913	658	3, 740	790		26, 140							
1914	5, 789	12, 151	570	26	30, 054							
1915	1, 488	4, 016	987		16, 164							
1916	3, 960	3, 086	464		2, 993							
1917	987	989	200		1, 345							
1922	5, 000	5, 114	2, 469	353	10, 040							
1923	3, 626	5, 512	4, 526	61	11, 705							
1924	2, 605	2, 055	1, 367	16	10, 404							
Seduction Point:												
1921	9, 500	9, 290	105	8	9, 185							
1923	5, 784	45, 397	257	155	1, 186							
Shelter Island:												
1920				508								
1923	366	2, 852	11, 556		10							
Sherman, Point:												
1920	7, 643	17. 649	7, 560		16, 852							
1921	5, 680	2, 450	355	34	18, 306							
1922	418	936	859	49	2, 791							
1923	2, 003	10, 797	1, 357	28	5, 576							
1924	3, 029	2, 824	1, 543	108	20, 335							
1925	729	971			14, 073							
William Henry Bay:												
1924		1, 963	8									
Unallocated:												
1883					107, 800							
1884					143, 000							
1885					26, 400							
1886					113, 300							
1887					143, 000							
1888					212, 300							
1889					504, 900							
1890					487, 300							
1891					578, 413							
1892					538, 604							
1893					418, 946							
1894	11, 000			7, 000	340, 000							
1895	7, 028			9, 453	310, 759							
1896	5, 852			10, 823	412, 519							
1897	11, 123			14, 796	321, 517							
1898	37, 228				327, 456							
1899	3, 934			12, 540	484, 950							
1900	10, 527		2, 409	10, 691	648, 443							
1901	38, 013		9, 614	7, 512	483, 569							
1902	63, 114		84, 192	5, 245	788, 913							

TABLE 3.—*Salmon caught and fishing appliances used in the Lynn Canal district, 1883 to 1927*—Continued

Year	Cobo	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated—Continued.												
1903	166, 512		147, 020	6, 293	796, 301							
1904	7, 216	14, 878	68, 046	770	858, 863							
1905	3, 300	30, 656	1, 962		244, 924							
1906	107, 961	95, 879	59, 572	1, 413	171, 866							
1907	14, 758	24, 626	52, 979	16, 327	147, 379							
1908	24, 521	25, 691	34, 686	313	211, 500							
1909		5, 046			234, 209							
1910	7, 155	18, 111	4, 834	789	97, 066							
1911	62, 332	127, 522	201, 064	1, 255	135, 041							
1912	24, 387	104, 099	376, 440	741	156, 692							
1913	11, 790	48, 311	72, 374	767	171, 693							
1914	17, 822	62, 707	72, 650	1, 117	128, 717							
1915	30, 635	62, 892	112, 620	275	114, 552							
1916	79, 534	136, 234	255, 774	442	94, 480							
1917	73, 407	115, 892	248, 249	839	102, 013							
1918	32, 146	131, 881	96, 933	4, 392	68, 239							
1919	48, 410	105, 859	53, 932	1, 484	93, 174							
1920	18, 098	46, 077	63, 609	1, 550	77, 764							
1921	3, 314	5, 511	19, 941		16, 452							
1922	8, 863	18, 639	50, 001		45, 053							
1923	15, 121	71, 407	366, 720		55, 512							
1924	8, 851	30, 188	31, 315	2, 584	4, 155							
1925	7, 631	10, 372	4, 488	213	5, 106							
1926	1, 679	9, 025	1, 045		182							
1927	2, 131	11, 916	32, 600	380	9, 800							
Total:												
1883					107, 800							
1884					143, 000							
1885					26, 400							
1886					113, 300							
1887					143, 000							
1888					212, 300							
1889					504, 900							
1890					487, 300							
1891					578, 413							
1892					538, 604							
1893					418, 946							
1894	11, 000			7, 000	340, 000							
1895	7, 028			9, 453	310, 759							
1896	5, 852			10, 823	412, 519							
1897	11, 123			14, 796	321, 517							
1898	37, 228				327, 456							
1899	3, 934			12, 540	484, 950							
1900	10, 527		2, 409	10, 691	648, 443							
1901	38, 013		9, 614	7, 512	483, 569							
1902	63, 114		84, 192	5, 245	788, 913							
1903	166, 512		147, 020	6, 293	796, 301							
1904	16, 830	69, 186	128, 046	914	1, 135, 392	2		12		149		3
1905	25, 483	35, 656	1, 962	558	371, 495	4		10		79		10
1906	169, 227	140, 271	59, 572	3, 180	565, 512			1		137		11
1907	17, 318	46, 780	123, 086	19, 862	273, 878					59	12, 750	8
1908	24, 521	37, 155	34, 686	2, 447	246, 251	2	100	1	75	45	12, 100	11
1909		15, 140			401, 283					41	11, 550	5
1910	23, 972	42, 280	188, 456	3, 089	541, 949	1	75			50	14, 250	7
1911	96, 592	241, 335	378, 308	2, 404	348, 480	1	50	1	100	84	22, 150	9
1912	33, 442	222, 328	427, 685	1, 621	316, 687			2	300	105	29, 110	11
1913	12, 949	53, 489	75, 864	917	207, 765					80	22, 750	10
1914	59, 817	160, 520	189, 703	1, 337	385, 488			4	525	50	15, 000	11
1915	33, 171	85, 828	115, 713	275	289, 662					31	9, 300	7
1916	112, 257	235, 859	258, 510	1, 942	238, 897					65	11, 400	11
1917	104, 955	173, 737	295, 218	7, 051	270, 296			1	150	47	13, 900	15
1918	54, 020	246, 330	143, 159	4, 512	192, 747			1	200	43	12, 500	11
1919	78, 343	297, 646	61, 031	2, 639	177, 309			14	2, 250	32	7, 200	10
1920	50, 294	135, 572	104, 633	2, 433	147, 856			4	610	48	8, 495	10
1921	46, 360	31, 645	69, 160	59	123, 939					47	11, 400	7
1922	33, 720	91, 861	115, 108	735	114, 845	2	300	2	320	27	7, 700	6
1923	48, 263	251, 233	448, 396	258	146, 646			7	1, 150	24	6, 450	7
1924	40, 642	149, 653	139, 615	4, 863	121, 140			8	1, 720	20	4, 000	7
1925	31, 117	119, 834	192, 986	1, 029	105, 460							7
1926	20, 235	139, 144	183, 091	335	94, 473					34	6, 800	7
1927	30, 642	63, 009	125, 108	673	70, 535					50	4, 250	8

NOTE.—The catch statistics used in this table from 1883 to 1893, inclusive, were obtained by taking the pack reported by Moser (1902) and multiplying the number of cases by 11 (the number of red salmon from this district which was required to pack a case of 48 one-pound cans, according to Moser's calculations). Data for the years from 1894 to 1903, inclusive, were obtained from the reports of Murray, Tingle, and Kutchin, who were special agents of the Treasury Department in Alaska during those years.

No catch was reported in the years omitted in any part of this table.

This table includes 3 catches of king salmon reported as taken by trollers, as follows: 16,221 in 1907, 879 in 1920, and 675 in 1925.

Perhaps the most striking peculiarity of this district is the apparent preference of the salmon in their northward migration for the eastern shore of the canal. Available data indicate that in 45 years fishing in Lynn Canal, catches along the western shore were limited to operations at St. James Bay and William Henry Bay in 1924, and at Point Howard in 1926, and that these catches included less than 20,000 fish of all species in either year. There is no evidence that any other salmon were taken on this shore south of Chilkat Inlet. Presumably the Chilkat and Chilkoot runs of red salmon enter from the ocean, chiefly through Cross Sound and Icy Strait, although it is possible that some may come in through Chatham Strait and Stephens Passage. The runs strike the west coast of Mansfield Peninsula between Hawk Inlet and Funter Bay, follow it northward to Point Retreat, touch Lincoln Island and the northwest coast of Shelter Island, and thence along the eastern shore of Lynn Canal to Eldred Rock and the Chilkat Islands, at which points the Chilkat runs are deflected to that river while the Chilkoot runs continue along the western shore of Chilkoot Inlet to the river of their origin. After passing Shelter and Lincoln Islands, this route of travel is clearly shown by the catches of traps located on that coast at Bridget Cove, Bridget Point, Point St. Mary, Point Sherman (which includes a catch at Sandspit in 1925), Eldred Rock, and Chilkat Islands. Fishing at these points has not been continuous unless, in the years for which no specific data are available, the catches were simply reported as coming from Lynn Canal.

Funter Bay, indenting Mansfield Peninsula at the south end of Lynn Canal, has produced salmon, chiefly chums and pinks, in 1919 and from 1924 to 1927. A few thousand reds and cohos and a few kings were also reported from this locality. The reports of these catches may all be viewed with considerable doubt. In the first place, if Funter Bay has a local run of salmon, there is little reason to suppose that it was not fished before 1919, as a cannery has been in operation on the bay for more than 30 years. In the second place, if these figures represent catches actually made in Funter Bay, it is difficult to explain why the locality was fished only 5 years and that red salmon, the most desirable species, were not taken in 1919 and only one was caught in 1924. Moreover, all of these catches were reported by companies having canneries some distance from Funter Bay, while the company which is located there, the one most likely to fish the bay if salmon were obtainable, reported none at all. It is probable that these catches came from traps on the shore of Mansfield Peninsula, north and south of Funter Bay.

The Mansfield Peninsula shore has been used for many years as a fishing ground for traps. Salmon were taken at Clear Point, False Point Retreat (which includes catches from "Cove" in 1926 and 1927), the Kittens, Naked Island and Point Retreat, and at several intermediate unnamed points. Traps in these waters take the first toll from the Lynn Canal runs after they leave Icy Strait. They were probably operated each year after their introduction into these waters, but catch records are not continuous, a fact difficult to understand unless salmon from these localities were reported merely as coming from Lynn Canal. A shore that is followed closely by migrating salmon, such as the Mansfield shore, is not apt to be abandoned unless legal prohibitions compel that action.

Berners Bay, the largest indentation on the eastern shore, is not an important producer of salmon. Small lots of cohos and chums were taken there in 5 years from 1919 to 1925, a few hundred reds in 4 years, and a handful of pinks in 2 years. Kings have not been reported at any time. The catch in 1925 includes a small lot of chums

and pinks reported from "Barnes Bay" which was presumably intended for "Berners Bay."

Many deficiencies exist in respect of the details of catches at Chilkat and Chilkoot Rivers. No information is available showing the catches at these rivers before 1904, yet fishing was carried on in both localities from 1883 to 1903. As mentioned above, these data appear in table 3 as unallocated catches. Even in subsequent years, catches were made at these rivers and reported merely as coming from Lynn Canal. Such faulty data are obviously not subject to detailed analysis, and it has been necessary to limit the study of the data to the total catches in Lynn Canal as a whole rather than those of any subdivision of the district. This procedure is not entirely satisfactory since not all of the salmon taken in the southern part of Lynn Canal came from runs to those waters; some were unquestionably destined to the tributaries of the northern part of Stephens Passage and mingled with the runs of Lynn Canal along the shore of Mansfield Peninsula; but, in a general way, the total figures will show the development and present status of the fishery.

The Chilkat catches include salmon reported from "Chilkat and Chilkoot Inlets and Lynn Canal" in 1909 and 1921; from "Chilkat and Lynn Canal" in 1923; and from "Kalhagu Cove, Kelgayu Bay, and Pyramid Harbor" in 1924. Chilkoot catches include fish from "Lynn Canal and Chilkoot Inlet" in 1907; from "Chilkat and Chilkoot Inlets and Lynn Canal" in 1909; from "Chilkoot Pass" in 1923; from "Chilkoot and Mud Bay" in 1923; and from "Flat Bay, Portage Cove and Tanani Bay" in 1924. The unallocated catches include, in addition to the early records, fish reported from "Icy Strait and Lynn Canal" in 1919; from "Lynn Canal and Icy Strait" in 1904; from "Lynn Canal and Chilkoot Inlet" in 1907; from "Chilkat and Chilkoot Inlets and Lynn Canal" in 1909 and 1921; from "Chilkat and Lynn Canal" in 1923; from "Chatham Strait and Lynn Canal" in 1912, 1914, and 1919; from "Lynn Canal and Stephens Passage" in 1923 and 1927; from Point Howard in 1926; and from "Salt Lake" in 1905.

The Chilkat and Chilkoot Rivers are the main source of the runs of red salmon entering Cross Sound. These runs were the first that were exploited in the northern section of southeastern Alaska and were eventually fished far from the streams of their origin. It is important to keep this point in mind in considering the size and condition of the Lynn Canal red-salmon runs. No record showing separately the catch at these two rivers before 1904 is available, nor is it certain that the later catches were accurately segregated. In many instances they were reported only as coming from Lynn Canal. It seems advisable therefore to confine this analysis to the total catch of red salmon in the Lynn Canal district rather than to undertake consideration of the data for each locality separately.

Figure 15 shows graphically the catch and the trend of the catch of red salmon in Lynn Canal for a period of 45 years. There was a gradual building up of catches until about 1904 at which time the exploitation of the fisheries in the Icy Strait district began; but from that year to the end of the period the story is one of a steady decline. On the same graph is shown the catch and trend of the catch of red salmon in Icy Strait; and it is quite apparent that, as the catch increased in Icy Strait, it declined in Lynn Canal. The effect of this shift of the fishery and the change from gill nets and seines to traps was immediately reflected in the poorer catches at Chilkat and Chilkoot Rivers and soon resulted in the permanent closing of the first canneries located on Chilkat Inlet. Although the catch after 1924 was undoubtedly affected by new regulations, it is not likely that there would have been much increase in the

number of reds caught in Lynn Canal without some relaxation in the intensity of fishing in Icy Strait.

Figure 16 shows the deviations of the catches from the trends in both districts. It is evident from this that there has been no marked correlation between the catches of red salmon in the two districts, if the entire period from 1902 to 1925 is considered, although this might have been expected since the catches are drawn from the same runs. There is, however, a definite positive correlation in the last few years of the period—from 1912 to 1925—and a slight negative correlation during the period from 1902 to 1911. The Pearsonian coefficients of correlation (r) have been calculated for these periods and are as follows: (1) For the period 1902–1911, -0.35 ± 0.19; for the period 1912–1925, $+0.68 \pm 0.098$; and for the entire period 1902–1925, $+0.013 \pm 0.136$. The positive correlation during the later period is unquestionably significant; the

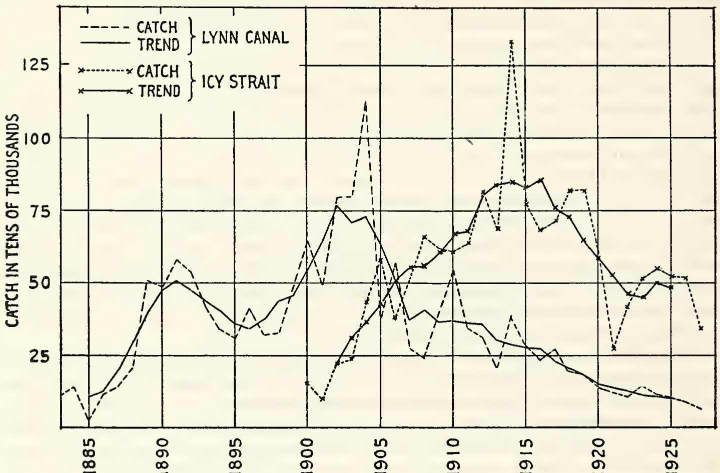

FIGURE 15.—Catch of red salmon in Lynn Canal and Icy Strait.

correlation during the earlier period is of doubtful significance; while the correlation for the entire period has certainly no significance due, obviously, to the combining of a positive with a negative correlation.

The interpretation of these phenomena is difficult; but it is interesting to note that the negative correlations occurred during the period in which the catch in Icy Strait was increasing while that in Lynn Canal was decreasing and that, after the peak of production in Icy Strait had been reached and the catches in both districts were decreasing, the correlation became distinctly positive. This is, of course, just what might have been expected if the trends had not been eliminated, but since the correlations are based on deviations from the trends, the influence of the change in the trends from opposed to parallel should have had no effect. Why there should have been a negative correlation in the early part of this period is very doubtful and we have no explanation to offer. In the case of the more significant positive correla-

tion in the catches since 1912 it appears very probable that this is due to the fact that the fisheries in the two localities draw largely upon the same runs. Economic factors may, however, be partly responsible for this correlation as can be seen from the fact that the deviations from the trends in 1921 were both negative and it is quite certain that the catch in 1921, at least in Icy Strait, was low because of the relaxed fishing effort.

There appears to be no definite cyclic fluctuation in these deviations from the trends. Nothing is known definitely of the typical age at maturity of these Chilkat and Chilkoot red salmon, but even if they should be similar the admixture of two races would, in all probability, wipe out any cycles in abundance even if such were present in the separate races.

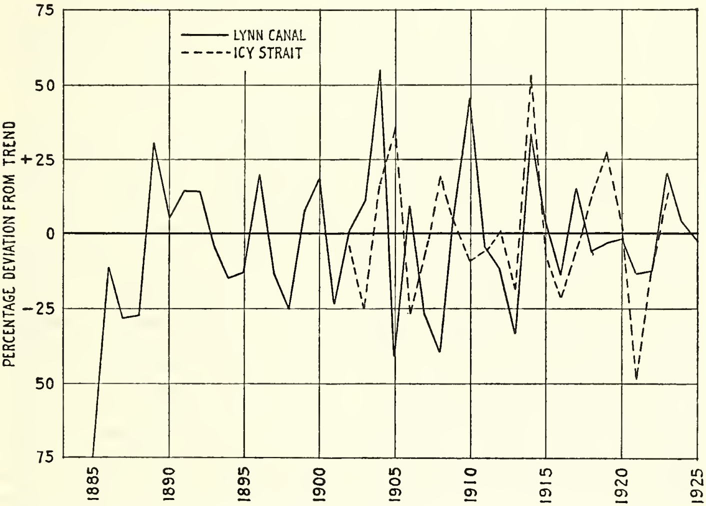

FIGURE 16.—Percentage deviations from trend of catch of red salmon in the Lynn Canal and Icy Strait districts.

Fair catches of pink, chum, coho, and king salmon have been made in Lynn Canal although these species were not as persistently fished as the reds. Cohos and kings were first reported in 1904, but were probably taken and counted as reds from the earliest exploitation of the salmon resources of the district. Rather large catches of kings were reported by the canneries on the canal from 1894 to 1903, but they came mostly from Taku Inlet. The catch of this species by nets has become decidedly insignificant as most of the kings are now taken with lines.

Cohos are taken regularly in this district, and there appears to be no indication that the supply is less abundant than it was 35 years ago. Fluctuations in catches have occurred, good years were followed by poor years, closed seasons, and closed areas have affected fishing, but the catches continue to be as good as they ever were.

Pinks and chums have constituted fairly important fisheries in the district for 20 years or more and are still obtained in quantities which are comparable to those

taken in the early years of exploitation. Unusually good catches have been made in a few years, poor catches have also appeared, but positive signs of depletion are not discernable in the statistical records here considered. That the district will continue to produce fair runs of these species, at least under the present limitations of fishing, appears to be a reasonable assumption.

CHATHAM STRAIT

The Chatham Strait district is bounded on the north by a line from the point at the south entrance of Funter Bay to Point Couverden and thence to Point Augusta, and on the south by a line from Cape Ommaney to Cape Decision; it is separated from Peril Strait by a line from Point Craven to Point Thatcher, and from Frederick Sound by a line from Point Gardner, passing just east of Yasha Island to a point on the shore of Kuiu Island 1 mile north of Kingsmill Point. Chatham Strait has many arms indenting the shores of Admiralty, Chichagof, Baranof, and Kuiu Islands, several of which have been notable producers of pink and chum salmon and have made fair contributions to the catch of the other species. (See fig. 17.)

Yet Chatham Strait, with all its length of more than 200 miles of shore line and numerous bays, has no exceptionally important salmon stream. There are many small streams tributary to the strait some of which support fair runs of fish, but the larger catches have come regularly from the strait, often at considerable distance from a stream. Some of the bays were also fair producers, but none of them approached in productivity the shore of Mansfield Peninsula between Funter Bay and Hawk Inlet, Fishery Point, Kingsmill Point, and the north shore of Tebenkof Bay a few miles eastward of Point Ellis. These larger catches at points several miles from a stream were made by traps which intercepted the main runs of salmon to Lynn Canal, Stephens Passage, and Frederick Sound. The important runs enter Chatham Strait from Icy Strait on the north or directly from the ocean through the southern entrance; small runs may also come through Peril Strait from the west and through Keku Strait from the south. The fish entering from the south tend to follow the Kuiu Island shore and for the most part are bound to the streams of Frederick Sound and Stephens Passage, though some go into the upper part of the strait, as was shown by tagging experiments in 1924 and 1925; but there is probably no significant movement of salmon in that direction north of Point Gardner. The runs from the north, differing from those of the south, show less preference for one side of the strait, as good catches have been made on both the Chichagof and Admiralty shores, but in the long run the shore of Admiralty Island unquestionably is preferred and leads in production.

Baranof and Chichagof Islands are decidedly more mountainous than Admiralty and Kuiu Islands, their streams are much more precipitous, particularly those of Baranof, shorter, and in several cases, seriously obstructed by natural barriers. The areas available for spawning are correspondingly reduced and in consequence these streams never did and never will support a salmon population equal to that of the eastern tributaries of Chatham Strait. All bays on the east coast of Baranof Island are small, Kelp Bay being the largest, and for the most part have only one or two tributaries which are accessible to salmon. The east coast of Chichagof Island is indented by the largest bays of the west side of Chatham Strait. Tenakee Inlet, the largest one, is 40 miles in length and extends in a northwesterly direction beyond the center of the island. It has several fair-sized tributaries which produced large

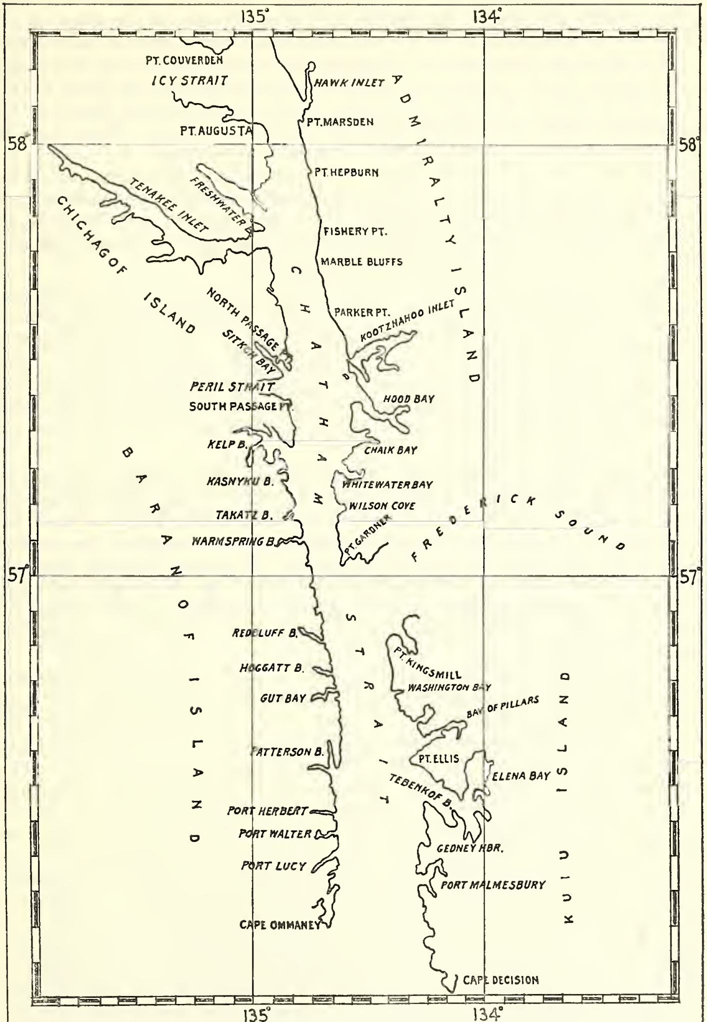

FIGURE 17.—Map of the Chatham Strait district.

catches of pink and chum salmon until the supply was seriously reduced by overfishing. Freshwater Bay is approximately 13 miles in length and receives one red salmon stream through Pavlof Harbor and several pink salmon streams near its head.

The Admiralty Island shore of Chatham Strait is very regular from Funter Bay to Kootznahoo Head, a distance of 50 miles which is broken only by Hawk Inlet at the southern end of Mansfield Peninsula. South of Kootznahoo Head are five indentations which have yielded moderate catches of salmon. These bays are successively smaller as the south end of the island is approached.

The west coast of Kuiu Island is extremely irregular. It is broken by Bay of Pillars and Tebenkof Bay, both rather deep indentations and once important producers of salmon, and by several small bays of lesser importance. In describing the territory fished by the Baranof Packing Co., whose cannery was located at Redfish Bay, Moser (1898, p. 117) reported in 1897 as follows:

> The streams are scattered over a territory fished by no other cannery and range on the outer coast from Cape Ommaney to Cross Sound and on both sides of Chatham Strait from Icy Strait to Cape Ommaney. It is one of the hardest fishing routes in Alaska. The streams all lie in unsurveyed districts and as a rule are small and uncertain. A stream that yields 4,000 to 5,000 redfish one year may not have enough the next to feed a native family. A stream in Chatham Strait, fished by this cannery, was prospected secretly and independently one year with great success by different parties. The following year they met at the mouth of the stream with big outfits, neither previously knowing the other's intentions, and where there had been thousands of fish the year before, there was not enough to salt a dozen barrels.

He was speaking of a time when only red salmon were wanted and his observations applied to streams used by that species. It would be interesting now to know the stream to which he referred and to review the history of the fishery at that locality through the 30 years that have intervened since his investigation, but unfortunately he did not record the name of the stream. It appears, however, that even in the early years of salmon exploitation in this district, runs were erratic, and a year of comparative abundance might be followed by a year of great scarcity, a condition which in no way could be attributed to overfishing, as the field had hardly been explored at that time.

Commercial fishing in Chatham Strait seems to date from 1889 with the building of canneries at Pavlof Harbor and at Redfish Bay though it is probable that the Lynn Canal canneries took fish from the upper part of the strait before that year. The canneries in the neighborhood of Sitka may also have taken salmon from Chatham Strait, but there is no positive proof that their operations were extended far beyond the immediate location of the canneries. Apparently the supply of salmon in the northern part of the strait was considered insufficient for the profitable operation of a cannery, or else it was found that a larger supply was more easily obtainable in the southern part of the strait, as the plant at Pavlof Harbor was moved in 1890 to Bay of Pillars. This cannery was burned in 1892, leaving the cannery at Redfish Bay in sole possession of the field until 1900, in which year a few salteries were opened. Through the next several years, however, the number of canneries gradually increased, though the old plants had been abandoned or had been destroyed, until at one time there were 13 canneries located within the district and fully as many more in other districts were taking salmon from its waters. Along with the establishment of more canneries there came a considerable shift in fishing methods, changing from movable gear to fixed appliances. Fishing in the bays continued to be largely in the hands of Indians operating seines, while that in the open waters of the strait was carried on almost

exclusively by the use of traps. Larger catches were made, therefore, in the strait than in the bays.

The growth of the industry in this district was not marked by any sudden developments or increase of activities until 1917 when, under the pressure of extraordinary conditions, through 4 years, 2½ times as many beach seines, 5 times as many purse seines, and 4 times as many traps were employed as had ever before been used, with the one exception that 38 purse seines were operated in 1908. This large increase in appliances raised the catch of all species, except reds, to levels that had not before been reached. With the return to normal world conditions, the speculative operators disappeared, fishing dropped back to its usual level and catches were reduced accordingly. After a year or two of relative inaction, the fisheries again began to receive increasing attention, and in a few seasons the number of seines and traps and the catches again increased in spite of the fact that several bays had been closed to fishing and closed seasons had been provided for extended periods.

The laws and regulations until 1924 were weak and ineffectual in providing even a fair measure of protection for the fisheries, and they had little or no effect in limiting the catch in any locality. The law of 1924, however, was a material forward step in fishery legislation and made it possible to bring complete protection to these fisheries at any time and in any locality. Accordingly, all fishing was prohibited for 20 days in August 1924, and Tenakee Inlet, Freshwater Bay, Whitewater Bay, and Wilson Cove were permanently closed to all commercial fishing for salmon. In 1925, additional closures included the head of the south arm of Chaik Bay, Warmsprings Bay, Basket Bay, south arm of Bay of Pillars, north arm of Tebenkof Bay, Gut Bay, Red Bluff Bay, and Falls Creek Bay. In the waters of Chatham Strait north of the fifty-eighth parallel of north latitude, fishing, except by lines and by gill nets from September 5 to October 15, was prohibited after August 6 to the end of the year. In the waters between the fifty-seventh and fifty-eighth parallels, fishing, except by lines, was prohibited after August 11; in the water south of the fifty-seventh parallel, fishing, except by lines, was prohibited from August 18 to September 24, and after October 15. These seasonal closings were continued in 1926 and 1927, and in 1926 the middle arm and part of the south arm of Kelp Bay were permanently closed. At the same time all streams of Sitkoh Bay were protected to a distance of 1,000 yards.

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part:												
Augusta, Point:												
1918	2,215	7,550	63,008	121	5,248							
1919	387	3,334	16,954	155	1,656							
1920	601	3,333	11,491	7	2,775							
1922	731	11,408	32,944	13	2,406							
1923	1,687	2,590	72,939	10	2,352							
1924	1,562	9,717	51,038	40	2,642							
1925	2,905	33,052	81,325	233	8,785							
1926	1,310	30,161	75,429	21	1,231							
1927	1,614	13,962	69,768	92	3,054							
Basket Bay:												
1896					21,175							
1900					61,500							
1904	3,000		40,000		86,000							
1912					2,968							
1918	2,101	28,905	40,723		314							
1920	133	8			892							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Contd.												
Basket Bay—Con.												
1922	150	152	2,345		523							
1923	25		70		910							
1924	209	316	5,819		221							
1926	1,137	35,657	65,544	18	962							
1927	2,289	36,376	71,413	44	2,340							
Caution, Point:												
1918	905	31,429	65,017		350							
1926	676	15,456	85,544		1,024							
1927	1,804	2,778	17,884	20	298							
Chaik Bay:												
1905		153,300										
1908	389	10,175										
1911	438	6,078										
1916		5,257										
1917	59	79,669	201,530	2	8							
1918	361	25,681	314	3								
1919	4,716	162,505	86,094	28	5,362							
1920	23	66,859	3,776									
1921		11,174	3,148		50							
1922	162	5,731	5,287	52								
1923	3,533	47,683	2,084		8							
1924	2,731	192,169	4,487		5							
1925	358	34,644	24,341		850							
1926	1	29,884	804		137							
1927	74	3,002	962		8							
Cosmos Cove:												
1925	1	230	989									
1926	1	2,240	286		2							
1927	3,139	27,375	67,006	86	1,422							
Dippy Cove:												
1923	1,030	4,131	61,061	32	1,527							
1924	536	11,261	42,159		504							
Distant Point:												
1918	4,340	26,269	76,434	27	2,493							
1922	2,370	11,408	109,774	47	2,554							
1923	2,234	11,897	144,257	40	2,435							
1924	1,411	34,256	77,495		2,448							
1925	1,629	70,760	87,427		1,837							
1926	830	24,853	64,161		837							
1927	4,722	10,414	41,518	46	820							
East Point:												
1919	18,962	15,341	70,650	154	138							
1922	2,782	13,429	34,856	42	2,610							
1923	2,280	6,249	67,872	1	1,043							
1924	3,730	18,520	22,695		1,920							
False Bay:												
1924	138	1,739	11,103		2,653							
1925	1,123	16,263	14,000	67	1,000							
1926	400	18,450	21,235		675							
1927	97	3,478	2,800	80	449							
Favorite Bay:												
1917	2,000											
1918		846	144									
1924		1,747	460		722							
1925	3	4,320	10,100		11							
1926		955										
1927		679	282		3							
Fishery Point:												
1913	2,027	7,032	152,910		2,383							
1914	2,309	4,535	38,215	36	3,145							
1915	747	11,717	536,448		2,687							
1916	5,091	6,213	102,807	1,203	2,375							
1917	4,911	20,408	777,330	60	5,995							
1918	3,837	7,191	78,226		3,165							
1919	3,334	13,504	55,345		2,213							
1920	1,010	6,509	48,300	164	2,573							
1923	7,764	10,169	204,497	26	3,968							
1924	6,764	49,256	314,606	40	1,052							
1925	1,172	5,648	28,608		1,462							
1926	1,787	20,698	103,491	862	4,129							
1927	757	4,526	37,727		1,179							
Freshwater Bay:												
1900					25,000							
1904	4,416											
1912	1,964	2,500	5,000		1,000							
1916	1,165	2,035	4,560		560							
1917	6,285	12,419	125,749	584	179							
1918		52,518	8,044									
1919	6,103	5,957	11,499	13	808							
1920		141	878									
1923	88	1,293	26,306		30							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Contd.												
Hawk Inlet:												
1905		5,000										
1910			35,401									
1911		68	27		189							
1920	5,610	29,392	158,720	26	8,450							
1921		71	896									
1923	1	452	4,492		51							
1924		5,361	26		1							
1925	3,541	46,099	92,570		17,623							
1926	1,565	64,278	83,319		12,282							
1927	2,903	32,547	61,002	95	8,826							
Hepburn, Point:												
1913	1,238	13,347	135,453		3,136							
1914	5,167	6,920	55,630	42	5,275							
1927	2,590	14,515	83,505	32	5,588							
Hood Bay:												
1911	1,160	773										
1912		2,164										
1913	50	323	1,023									
1916	1,161	6,226										
1917	3,764	16,234	40,231		10							
1918	216	82,609	14,094		36							
1919	1,886	65,941	22,264	81	1,295							
1920	45	25,616	4,458	43	5							
1921		4,859	5,920									
1922		3,865	4,528		3							
1923	257	4,556	30,383		2							
1924	1,347	42,827	13,122		1							
1925	11	54,140	22,331		93							
1926	14	54,606	25,110		53							
1927	17	11,463	1,692		17							
Iyoukeen Cove:												
1918	905	28,328	31,042	121	1,720							
1919		2,794	24,972	33	71							
1922	395	16,180	15,103	6	1,011							
1924	196	26,863	15,427		688							
1926	361	13,669	5,761		846							
1927	538	11,790	14,129	205	1,155							
Kasnyku Bay:												
1927	720	1,600	10,730		50							
Kelp Bay:												
1916		2,153	2,146									
1917	1,000	1,591	4,233		1							
1918	50	9,620	9,835		3							
1919	10	18,595	30,137	3	2,314							
1920	275	13,033	13,652	1	100							
1921		861										
1922	548	4,509	21,788	7	1,603							
1923	1,249	4,829	82,560		1,327							
1924	198	22,177	100,581		2,954							
1925	1,113	22,003	75,671		77							
1926	3	3,967	22,421		1							
1927		714	1,569									
Kootznahoo Inlet:												
1918		5,722	5,114		587							
1919	420	837	428		563							
1920					102							
1921	56				3,058							
1922			35		1,291							
1925	2	1,435	6,445		458							
1926		24	3,947		896							
1927		43	85		601							
Lone Tree Islet:												
1927	960	9,656	12,175	6	301							
Marble Bluff:												
1917	3,257	6,807	241,875	88	1,431							
1918	3,213	8,240	106,776		4,066							
1922	1,136	2,907	92,428	80	1,545							
1923	1,617	756	104,482	24	2,334							
1924	9,443	39,690	144,739	898	4,034							
1925	2,257	31,308	68,200	82	3,074							
1926	2,879	50,311	211,835	316	6,434							
1927	1,140	15,103	54,167	129	1,166							
Marsden, Point:												
1922	815	2,420	27,270	65	2,000							
1923	3,802	7,033	102,852	100	8,000							
1924	870	4,780	38,000	250	6,000							
1926	1,000	18,000	63,958	42	9,000							
1927	1,000	5,000	52,800	200	3,000							
Moonshine Point:												
1924	602	15,212	46,723		529							
1926	606	18,100	30,839		410							
1927	1,667	4,338	14,633	7	178							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Contd.												
Morris Reef:												
1924	3, 012	23, 198	59, 123		2, 199							
1925	2, 000	10, 328	80, 000		6, 000							
1926	2, 880	8, 000	87, 320	160	2, 500							
North Passage Point:												
1924	1, 491	13, 342	29, 835	40	2, 390							
1925	2, 660	39, 485	40, 257	42	4, 676							
1926	1, 235	27, 326	33, 477		82							
1927	642	6, 960	13, 082	3	821							
Parker Point:												
1916	3, 723	2, 582	50, 855	68	1, 488							
1917	9	1, 555	1, 510	239	419							
1919		668	26, 256	78	384							
1922	5		8, 161									
1923	166	675	6, 395	3	397							
1924	7	1	9, 111									
1925	51	4, 120	3, 700	14	150							
1927	529	7, 205	22, 178	151	677							
Peninsula Point:												
1920	1, 557	12, 969	13, 189	12	990							
1922	717	6, 576	16, 721	6	881							
Poison Water:												
1923	38	10	1, 527									
1924			4, 336									
1926	35	453	1, 058		45							
Rocky Bay:												
1925	3, 504	54, 301	110, 537		7, 006							
1926	2, 000	7, 119	129, 310		4, 705							
Rocky Point:												
1915	199	5, 102	15, 436	87	3, 513							
1918	3, 821	4, 069	20, 607	51	3, 381							
1919	4, 232	5 778	13, 515	134	1, 999							
1927	1, 178	1, 997	14, 638	8	166							
Sitkoh Bay:												
1890	2, 354				4, 902							
1895	1, 252				4, 260							
1896					15, 794							
1897					566							
1900					30, 000							
1904			20, 000		12, 000							
1918	1, 306	950	13, 160	35	833							
1921	112				552							
1922	3				3, 462							
1924	4	625	13, 959		234							
1925	4	28	3, 911		248							
1926		17	678		337							
1927		2	2		122							
South Passage Point:												
1919		10, 313	53, 105									
1922	3, 370	18, 500	49, 181	63	3, 226							
1923	1, 313	6, 490	90, 674	31	1, 416							
1924	9, 115	33, 567	61, 334	40	2, 191							
1925	5, 587	69, 476	118, 645	78	14, 296							
1926	2, 749	95, 362	175, 008	325	2, 927							
1927	3, 864	55, 869	81, 329	125	6, 933							
Square Cove:												
1924	3, 316	4, 050	20, 543	6	4, 282							
1925	265	1, 817	2, 345	3	1, 770							
1926	1, 018	6, 484	73, 546	70	6, 428							
1927	1, 231	6, 312	47, 814	58	3, 877							
Tenakee Inlet:												
1909		38, 460	115, 380									
1912	3, 919	5, 500	10, 000		2, 000							
1913	129	400										
1914		4, 667	1, 569		61							
1916	3, 305	19, 566	113, 368	2	284							
1917	13, 997	50, 358	483, 830	511	3, 547							
1918	5, 096	401, 169	122, 169	416	3, 795							
1919	4, 562	76, 754	76, 686	68	7, 458							
1920	2, 856	37, 195	17, 574	441	949							
1921		78, 462	13, 891									
1922	123	42, 176	35, 645		156							
1923	158	6, 349	68, 220	5	691							
1924	1	6, 129	832									
Thatcher Point:												
1923	649	3, 160	34, 874	1	733							
Village Point:												
1924	2, 208	11, 207	30, 802	22	8, 133							
1925	16	101	1, 015		1, 759							
1926	128	14, 246	52, 801		225							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Contd.												
White Rock:												
1904			37,000									
1914					142							
1918	888	24,513	22,713		1,528							
1919	2,114	8,487	36,465	169	2,795							
1924		876	1,443									
1925	2	1,331	3,549		28							
1926		14	1,880		1							
1927		1	66		1							
Whitewater Bay:												
1918	132	12,524	3,653		32							
1919	63	20,806	8,307	2	599							
1920	28	6,526	2,247	23	56							
1923	36	2,162	4,407		126							
Wilson Cove:												
1907		18,503	1,652									
1908		78,053	52,441									
1909		38,495	101,332									
1911		12,701	4,702									
1912		15,602	20,962									
1917	9	8,898	73,406		1							
1918	1,753	79,656	74,406	33	406							
1919	829	30,171	8,545		27							
1920	423	12,035	22,897	43	456							
1921	2,705	10,443	7,557	63	726							
1922	2,740	6,315	23,441		1,403							
1926	553	9,815	40,980		655							
Woody Point:												
1927	3,820	5,617	18,405	45	488							
Unallocated:												
1892					21,875							
1900				100	77,700							
1901	16,923		920,890	629	131,055							
1902	6,000		488,000		128,080							
1903	40,417		239,431		241,175							
1904	22,000	7,000	280,000	600	101,200							
1905	22,324	167,689	330,536		93,664							
1906	26,902	206,643	811,677	923	177,200							
1907	36,245	342,553	1,132,174	4,220	121,394							
1908	21,106	535,954	1,418,825	239	256,619							
1909	20,740	116,577	556,302	974	304,351							
1910	30,594	244,256	473,181	638	150,892							
1911	55,724	418,065	1,302,801	5,383	158,767							
1912	61,224	587,250	1,254,620	8,428	242,996							
1913	40,259	212,851	1,723,345	7,372	203,418							
1914	68,481	325,955	959,725	3,818	215,115							
1915	59,966	198,543	2,154,421	5,308	235,563							
1916	47,377	229,720	1,874,378	1,757	122,974							
1917	75,873	314,899	3,318,157	4,338	259,122							
1918	68,168	962,572	2,139,992	6,188	214,099							
1919	121,938	882,358	1,571,551	24,406	177,870							
1920	74,476	551,020	1,023,242	5,767	156,347							
1921	45,782	408,279	426,767	1,473	87,020							
1922	52,066	156,962	917,076	5,389	79,322							
1923	24,028	114,816	1,098,224	12,797	58,947							
1924	23,460	165,125	561,028	975	75,786							
1925	20,783	299,432	414,865	2,344	82,209							
1926	29,778	325,017	919,992	2,333	83,856							
1927	47,948	215,704	797,253	5,739	58,827							
Total:												
1890	2,354				4,902							
1892					21,875							
1895	1,252				4,260							
1896					36,969							
1897					566							
1900				100	194,200							
1901	16,923		920,890	629	131,055							
1902	6,000		488,000		128,080							
1903	40,417		239,431		241,175							
1904	29,416	7,000	377,000	600	199,200			8				2
1905	22,324	325,989	330,536		93,664	1		17				4
1906	26,902	206,643	811,677	923	177,200			12				3
1907	36,245	361,056	1,133,826	4,220	121,394	1	100	12	1,920			2
1908	21,495	624,182	1,471,266	239	256,619			30	5,600			4
1909	20,740	193,532	773,014	974	304,351			13	2,425			2
1910	30,594	244,256	508,582	638	150,892	1	75	14	2,490			2
1911	57,322	437,685	1,307,530	5,383	158,956	1	75	17	3,000			11
1912	67,107	613,016	1,290,582	8,428	248,964	1	75	16	2,920			14
1913	43,703	233,953	2,012,731	7,372	208,937	2	225	12	2,100			13
1914	75,957	342,077	1,055,139	3,896	223,738			11	1,770			12
1915	60,912	215,362	2,706,305	5,395	241,763			10	1,680			21
1916	61,822	273,752	2,148,114	3,030	127,681			12	1,740			14
1917	111,164	512,838	5,267,851	5,822	270,713			42	6,460			20

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Contd.												
Total—Continued.												
1918	99,307	1,800,361	2,895,471	6,995	242,056	3	300	52	9,250			38
1919	169,556	1,324,143	2,112,773	25,324	205,552	13	1,075	93	18,205			50
1920	87,037	764,636	1,320,424	6,527	173,875	8	400	52	11,710	2	300	59
1921	48,655	514,149	458,179	1,536	91,406	10	800	22	4,160			16
1922	68,113	302,538	1,396,583	5,770	103,996	9	450	35	5,680			30
1923	51,955	235,300	2,208,176	13,070	86,297			35	5,820			37
1924	72,351	734,011	1,680,826	2,311	121,589			30	5,005			35
1925	48,987	802,321	1,290,831	2,863	153,412			26	4,715			35
1926	52,946	895,162	2,379,734	4,147	140,680			20	3,350			36
1927	85,243	509,026	1,610,614	7,171	102,367			29	5,308			45
Southern part:												
Falls Creek Bay:												
1913			874		1,279							
1914	771	1,005	1,564		2,479							
1915	190	90	1,284		3,586							
1919	333	2,187	11,125		9,615							
1920	49	65	3,235	1	3,717							
1921			522		1,810							
1922	116	22	409		3,214							
Gedney Harbor:												
1912	151	1,083	1,822		895							
1913	105	8,048	10,794		125							
1914		234	537									
1915			4,300		119							
1916		2,120										
1917	36	8,193	7,900		18							
1918	47	17,344	13,493		676							
1919		7,365	17,092		357							
1922	5	1,355	166		782							
1925	6	7,987	3,355		352							
1926		250	17		138							
1927	154	1,238	1,249		1,902							
Gut Bay:												
1892	970				1,673							
1893	293				2,766							
1894					630							
1895					6,716							
1896					2,326							
1904					20,000							
1905		15,000			7,000							
1906					2,500							
1908					1,302							
1909					2,703							
1910	600				4,905							
1911	550				4,371							
1912			10		100							
1913					1,723							
1914	36	12			1,777							
1915	68				3,234							
1916	288	9,416	408		12,009							
1917	175				1,057							
1918					1,500							
1919		1,200	8,290		22,572							
1920	438	1,920	960	1	10,402							
1921	97	2	367		7,120							
1922	28	65	302		4,514							
1923					215							
1924	4	662	194		10,551							
Herbert, Port:												
1912	136		4		262							
1913					201							
1914	1				521							
1918		549	411		32							
1922					272							
1924	8	4	131		1,712							
1925	29	789	84		1,111							
1926	64	1,832	313		4,063							
1927	311		2,362		430							
Kingsmill, Point:												
1915	5,995	12,869	401,762	737	19,236							
1918	7,839	109,546	412,486	74	4,617							
1919	13,175	117,531	171,795	413	15,551							
1920	1,400	65,390	123,145	175	5,070							
1922	4,006	21,721	176,008	14	7,098							
1923	6,750	34,810	208,070	30	11,910							
1924	22,081	97,759	940,383	159	16,197							
1925	11,795	124,361	145,901	223	9,095							
1926	11,624	40,637	802,242	43	16,720							
1927	27,036	84,561	307,752	450	9,189							
Malmesbury, Port:												
1907					72							
1908					186							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Contd.												
Malmesbury, Port—Continued.												
1909					84							
1911			1,168		5,041							
1912	17	2,403	13,656		2,488							
1913	242	597	15,646		1,752							
1914		585	1,436		452							
1915	50	1,337	16,626		544							
1916	167	5,912	2,848		2,404							
1917	12	13,422	34,900		67							
1918	79	5,853	1,678		2,721							
1919	400	19,774	29,189		1,398							
1920	2	12,079	10,028		3,567							
1922	1				221							
1924	469	6,502	10,054		2,901							
1925	9	7,232	10,875		1,518							
1926	193	3,117	20,182		1,752							
1927	27	2,398	2,580		2,022							
Patterson Bay:												
1918	7	6	409		2,173							
1919			3,023									
1923		856	7,628									
1924		1,078	8,580		1							
1925		4,085	1,628									
1927	99	1,244	18,459		158							
Pillars, Bay of:												
1892	3,665				9,842							
1893					2,605							
1894					8,740							
1895	2,836				14,572							
1896	3,607				15,834							
1897	957				11,709							
1898					10,000							
1900					22,500							
1904	12,000	2,000	36,400		14,500							
1905	8,000	16,000	25,000		15,000							
1906	12,500	30,000	25,000		30,000							
1907		40,600			12,000							
1908	13,000	16,600	26,000		17,000							
1909	5,150	18,758	12,000		3,700							
1910	2,000				19,400							
1911	4,000		39,775		12,000							
1912	1,385	10,093	2,632		7,037							
1913	4	5,140	6,448		2,278							
1914	923	5,355	7,753		15,045							
1915		1,927	25,142		12,089							
1916	3,205	16,996	12,534		13,267							
1917	686	14,652	42,618		8,790							
1918	1,195	27,970	24,604		8,854							
1919	1,001	28,856	10,465	1	4,160							
1920	4,021	23,277	9,136	2	3,645							
1921		3	7		4,070							
1922	273	4,680	11,331		6,331							
1923					12,000							
1924	163	16,076	3,426		11,023							
1925	202	84,458	9,701		70							
1926	5	39,892	11,027		13							
1927	13	3,734	686		20							
Red Bluff Bay:												
1904					6,500							
1905					5,000							
1906					5,000							
1907					14,000							
1908			80,000									
1911		14,000	1,000									
1912	16	176	745	12	202							
1913		414	3,972									
1914					96							
1915		175	395		812							
1916	310	797	7,691		7,596							
1917	500											
1918	45	3,160	3,694		2,607							
1919		6,122	8,897									
1920	2	1,113	1,488		2							
1921			310		425							
1923		3	221		129							
1924	1	33	4,296		1							
1927	1	2	13		170							
Tebenkof Bay:												
1892					5,990							
1893					3,529							
1895					730							
1896					1,500							
1897					4,304							

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Contd.												
Tebenkof Bay—Con.												
1900					7,000							
1904	6,000		50,000		55,000							
1905	9,000	7,000	75,000		30,000							
1906	4,000	8,000	297,000		41,290							
1907	8,540	60,000	274,000		36,000							
1908			243,000		35,000							
1909		12,000	452,100		36,106							
1910	3,500	76,000	200,000		39,554							
1911	9,370	97,736	377,905		30,428							
1912	4,575	93,468	94,928	5	8,134							
1913	1,972	84,826	167,448		4,850							
1914	2,924	43,773	49,018		6,312							
1915	358	4,491	85,727		12,226							
1916	3,285	1,902	42,163	2	9,081							
1917	5,382	75,379	813,992	5	6,472							
1918	13,296	148,043	365,616	999	20,877							
1919	3,374	145,533	88,505	30	3,800							
1920	4,512	90,185	39,526	61	12,628							
1921	16,253	60,253	29,412	1,576	7,208							
1922	22,059	117,974	146,856	311	16,294							
1923	27,987	45,443	365,122	1,340	42,792							
1924	43,661	192,434	329,263	5,387	15,355							
1925	1,770	175,474	77,133	1	1,624							
1926	8,793	94,146	314,958	513	13,033							
1927	8,071	55,906	71,277	98	6,513							
Walter, Port:												
1916		46,548	3,213									
1917		1,038	9,596									
1919			1,343									
1922	4		923									
1927		111	492									
Washington Bay:												
1917	404	15,313	121,136		411							
1924	967	5,892	69,870		967							
1925	521	13,504	25,755	2	1,071							
Unallocated:												
1902	13,500		175,000		50,000							
1903	4,033		4,867		4,000							
1905		4,000	12,000		43,000							
1908		362			9,703							
1911				3,274								
1912	74	69,807	37,557	24,941								
1913	11,961	32,619	100,421	21,598	1,307							
1914	902	256	2,322	16,864	5,307							
1915	3,401	165	6,836	58,313								
1916	62,366	31,488	390,220	107,695	22,928							
1917	79,519	342,432	1,993,133	110,287	12,019							
1918	104,922	633,576	1,921,948	87,465	24,251							
1919	149,637	398,407	1,219,745	190,461	68,063							
1920	51,782	607,492	1,339,895	93,958	53,566							
1921	61,270	22,469	37,449	174,462	2,060							
1922	27,122	1,411	185,131	74,452	2,743							
1923	45,286	26,895	393,201	128,261	6,258							
1924	44,116			373,427								
1925	99,744	155,601	350,326	132,097	27,156							
1926	77,504	75,635	116,248	97,876	8,832							
1927	65,607	10,946	52,856	146,753	11,198							
Total:												
1892	4,635				17,505							
1893	293				8,900							
1894					9,370							
1895	2,836				22,018							
1896	3,607				19,660							
1897	957				16,013							
1898					10,000							
1900					29,500							
1902	13,500		175,000		50,000							
1903	4,033		4,867		4,000							
1904	18,000	2,000	86,400		96,000			6				
1905	17,000	42,000	112,000		100,000			1				
1906	16,500	38,000	322,000		78,790			6				1
1907	8,540	100,600	274,000		62,072			10	1,600			
1908	13,000	16,962	349,000		63,191			8	1,265			
1909	5,150	30,758	464,100		42,593	6	900	7	1,160			
1910	6,100	76,000	200,000		63,859	4	600	8	1,300			
1911	13,920	111,736	419,848	3,274	51,840	2	320	6	1,025			2
1912	6,354	177,030	151,354	24,958	19,118	4	740	9	1,965			5
1913	14,284	131,644	305,603	21,598	13,515	6	910	9	1,620			5
1914	5,557	51,220	62,630	16,864	31,989	3	600	9	1,490			3
1915	10,062	21,054	542,072	59,050	51,846			10	1,570			2
1916	69,621	115,179	459,077	107,697	67,285			10	1,630			5
1917	86,714	470,429	3,023,275	110,292	28,834	7	850	38	6,525			11

TABLE 4.—*Salmon caught and fishing appliances used in the Chatham Strait district, 1890 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Contd.												
Total—Continued.												
1918	127, 430	946, 047	2, 744, 339	88, 538	68, 308	9	795	32	7, 175	4	214	30
1919	167, 920	726, 975	1, 569, 469	190, 905	125, 516	2	100	28	5, 725	------	------	46
1920	62, 206	801, 521	1, 527, 413	94, 198	92, 597	12	1, 700	28	5, 590	------	------	46
1921	77, 620	82, 727	68, 067	176, 038	22, 693	------	------	6	1, 150	------	------	6
1922	53, 614	147, 228	521, 126	74, 777	41, 469	------	------	16	2, 570	------	------	23
1923	80, 023	108, 007	974, 242	129, 631	73, 304	------	------	3	580	------	------	11
1924	111, 470	320, 440	1, 366, 197	376, 973	58, 708	------	------	30	5, 100	------	------	8
1925	114, 076	573, 491	624, 758	132, 323	41, 997	------	------	24	4, 245	------	------	10
1926	98, 183	255, 509	1, 264, 987	98, 432	44, 551	------	------	12	2, 060	------	------	6
1927	101, 319	160, 140	457, 726	147, 301	31, 602	------	------	30	5, 462	------	------	9
Grand total:												
1890	2, 354	------	------	------	4, 902	------	------	------	------	------	------	------
1892	4, 635	------	------	------	39, 380	------	------	------	------	------	------	------
1893	293	------	------	------	8, 960	------	------	------	------	------	------	------
1894	------	------	------	------	9, 370	------	------	------	------	------	------	------
1895	4, 088	------	------	------	26, 278	------	------	------	------	------	------	------
1896	3, 607	------	------	------	56, 629	------	------	------	------	------	------	------
1897	957	------	------	------	16, 579	------	------	------	------	------	------	------
1898	------	------	------	------	10, 000	------	------	------	------	------	------	------
1900	------	------	------	100	223, 700	------	------	------	------	------	------	------
1901	16, 923	------	920, 890	629	131, 055	------	------	------	------	------	------	------
1902	19, 500	------	663, 000	------	178, 080	------	------	------	------	------	------	------
1903	44, 450	------	244, 298	------	245, 175	------	------	------	------	------	------	------
1904	47, 416	9, 000	463, 400	600	295, 200	------	------	14	------	------	------	2
1905	39, 324	367, 989	442, 536	------	193, 664	1	------	18	------	------	------	4
1906	43, 402	244, 643	1, 133, 677	923	255, 990	------	------	18	------	------	------	4
1907	44, 785	461, 656	1, 407, 826	4, 220	183, 466	1	100	22	3, 520	------	------	2
1908	34, 495	641. 144	1, 820, 266	239	319, 810	------	------	38	6, 865	------	------	4
1909	25, 890	224, 290	1, 237, 114	974	346, 944	6	900	20	3, 585	------	------	2
1910	36, 694	320, 256	708, 582	638	214, 751	5	675	22	3, 790	------	------	2
1911	71, 242	549, 421	1, 727, 378	8, 657	210, 796	3	395	23	4, 025	------	------	13
1912	73, 461	790, 046	1, 441, 936	33, 386	268, 082	5	815	25	4, 885	------	------	19
1913	57, 987	365, 597	2, 318, 334	28, 970	222, 452	8	1, 135	21	3, 720	------	------	18
1914	81, 514	393, 297	1, 117, 769	20, 760	255, 727	3	600	20	3, 260	------	------	15
1915	70, 974	236, 416	3, 248, 377	64, 445	293, 609	------	------	20	3, 250	------	------	23
1916	131, 443	388, 931	2, 607, 191	110, 727	194, 946	------	------	22	3, 370	------	------	19
1917	197, 878	983, 267	8, 291, 126	116, 114	299, 547	7	850	80	13, 015	------	------	31
1918	226, 737	2, 746, 408	5, 635, 810	95, 533	310, 364	12	1, 095	84	16, 425	4	214	68
1919	337, 476	2, 051, 118	3, 682, 242	216, 229	331, 068	15	1, 175	121	23, 930	------	------	96
1920	149, 243	1, 566, 157	2, 847, 837	100, 725	266, 472	20	2, 100	80	17, 300	2	300	105
1921	126, 275	596, 876	526, 246	177, 574	114, 099	10	800	28	5, 310	------	------	22
1922	121, 727	449, 766	1, 917, 709	80, 547	145, 465	9	450	51	8, 250	------	------	53
1923	131, 978	343, 307	3, 182, 418	142, 701	159, 601	------	------	38	6, 400	------	------	48
1924	183, 821	1, 054, 451	3, 046, 023	379, 284	180, 297	------	------	60	10, 105	------	------	43
1925	163, 063	1, 375, 812	1, 915, 589	135, 186	195, 409	------	------	50	8, 960	------	------	45
1926	151, 129	1, 150, 671	3, 644, 721	102, 579	185, 231	------	------	32	5, 410	------	------	42
1927	186, 552	669, 166	2, 068, 340	154, 472	133, 969	------	------	59	10, 770	------	------	54

NOTE.—No catch was reported in the years not shown in any division of this table.

In reviewing the Chatham Strait fisheries, it was found desirable to divide the district into two parts—northern and southern—on account of the distinct runs which enter the strait from opposite directions, the arbitrary line of division being the fifty-seventh parallel of north latitude. Table 4 gives the entire catch of salmon in Chatham Strait from the year of the earliest available records down through 1927. Most of the catches before 1904 were unallocated. The figures given for these years were taken from Moser's reports and the reports of the special agents of the Treasury Department. Several consolidations of catches were made when it appeared that localities had been given different names by the fishery companies, or where names were misspelled. In many cases catches which were reported as having come from two or more districts were allocated to the waters named only after a painstaking examination of the records of each individual operator in each year. The same ratio of division could not be used in each case, yet the allocations were made with due regard to all the information then available. In this way catches that were reported from Chatham Strait and Frederick Sound in 1919 were divided between the two

districts on the basis of the probable catch in each district by the operators concerned. The same procedure was followed in allocating the catches from "Icy Strait, Chatham Strait, Peril Strait and Bays" in 1905 to 1907, and 1909 to 1919; from "Icy Strait and Chatham Strait" in 1905, 1907–1909, 1911, 1915–1921, and 1923; from "Sumner Strait and Whitewater Bay" in 1919; from "Tenakee Inlet and Freshwater Bay" in 1918; and from "Chatham Strait and Tenakee Inlet" in 1918. The catches at Falls Bay in 1919 and 1920, and from Falls Creek in 1914, 1915, and 1921 were combined with the catches from Cascade Bay and shown in the table under the name of Falls Creek Bay; catches from Gypsum Cove were added to those from Iyoukeen Cove; those from Keep Bay with the Kelp Bay catches. Kootznahoo Inlet data include catches from Calico Bay in 1926 and 1927, from Kanalku Bay in 1927, and from Mitchell Bay in 1920 and 1926. The catch reported from South Pass in 1927 was combined with that from South Passage Point; White Rock catches include those from Whiterock Bay in 1925; Point Kingsmill catches were combined with those from Kingsmill Beach and Shore in 1919, 1922, and 1925–1927. Tebenkof Bay catches include those reported from Kuiu Bay in 1904–1907, 1909–1911, 1913–1917, 1922, 1925, and 1926, from Kuku Bay in 1914 and 1917, and from Kuaka Bay in 1905. The unallocated catches also include salmon reported from Cape Gray in 1923, Calheen and Point Wilson in 1919; Angoon in 1927; Drake Sound and Point Ellis in 1925; Killisnoo and Vogel Spit in 1917; Point Deloris in 1924; Soll Bay, Waterfall, and Port Lucy in 1927; Lull Point, Mile Rock, and "K & B" in 1920; Game Cove and Poison Water in 1926; Lagoon in 1904; Baranof Island in 1923 and 1927; Kuiu Island in 1919 and 1920; Elk Point in 1914 and 1920; Boat Harbor in 1916; Port Conclusion in 1913, 1915, 1918, and 1922; and Port Alexander in 1918 and 1920. The unallocated catches also include part of the salmon reported from Frederick Sound, Keku and Chatham Straits and tributaries in 1913; from Saginaw Bay and Chatham Strait in 1912; from Chatham Strait and west coast of Prince of Wales Island in 1919; from Chatham Strait, Frederick Sound, and Stephens Passage in 1923; and from Chatham and Sumner Straits in 1914 and 1918.

In the table are listed 41 localities in the northern part of Chatham Strait from which considerable numbers of salmon have been taken. Of these, 24 are trap locations, 10 of which are on the east shore of Chichagof Island, 1 on the east shore of Baranof Island, and 13 on the west shore of Admiralty Island. The Chichagof locations are Point Augusta, East Point, False Bay, Iyoukeen Cove, Morris Reef, North Passage Point, Peninsula Point, Rocky Bay, South Passage Point, and White Rock; the Baranof location is Point Thatcher; and the Admiralty locations are Point Caution, Distant Point, Fishery Point, Point Hepburn, Lone Tree Islet, Marble Bluff, Point Marsden, Moonshine Point, Parker Point, Rocky Point, Square Cove, Village Point, and Woody Point. Traps were also located at unnamed places on the shores of these islands and in some of the bays, notably Chaik, Freshwater, and Hood Bays, Tenakee Inlet, and Wilson Cove, and augmented the catches in these waters by many thousands of salmon. The catches along the shore of Mansfield Peninsula were also made by traps, but it was not possible to segregate them from other catches which were merely reported as coming from Chatham Strait, so they were included in the unallocated catches of the district, although it is recognized that they constituted a considerable part of such catches. The traps on the east side of the strait made far better catches than those on the west side, showing very definitely that salmon coming from Icy Strait prefer the Admiralty shore, but the bulk of the catch was made north of Kootznahoo Inlet. The records certainly indicate that the traps

between Distant Point and Point Gardner made comparatively small catches, and the farther south they were located the fewer fish they caught. This same condition existed on the west side of the strait, as no large catches have ever been reported from waters south of Kelp Bay. The trap catches are easily recognized by their greater uniformity and the presence of all species, whereas fishing in the bays by seines is characterized by wide fluctuations and intervals during which, apparently, no fishing was conducted.

According to available data, the commercial utilization of salmon in this district began in 1890 at Sitkoh Bay, that being one of the few localities where red salmon were found. A few years later Basket Bay and Freshwater Bay were fished for reds, if, indeed, they were not exploited at the time of the opening of the first cannery in the district. The early records are not complete and allowances must be made, therefore, in any consideration of the data for those years. The period from 1890 to 1900 may well be termed the pioneer days of the salmon industry in this district; canneries and salteries were few; red salmon almost exclusively were sought which necessarily confined fishing to red-salmon streams and involved running hither and yon for a few thousand fish. In time it was evident that there were not enough red salmon available in the entire district to support even one cannery and if a salmon industry were to be successfully established here, it would have to be based on the utilization of the chums and pinks, the most abundant species in these waters. In 1901, nearly 1,000,000 pink salmon were taken in the northern part of Chatham Strait; the first important catch of cohos was also made in that year. Three years later a small catch of chums was made, traps were first used in the strait, and a fishery industry which until now had shown little promise of growth and development at last gave evidence of permanent stability and the once neglected species of salmon became the chief support of the infant industry. The catch did not progress steadily from year to year, but fluctuated according to the number of plants in operation and the amount of gear employed. There had been no intensive fishing and consequently no diminution of the supply of salmon, so that the catches were almost entirely dependent upon the intensity of fishing. Only five known localities were fished in 1904—Basket Bay, Freshwater Bay, Sitkoh Bay, White Rock, and the strait proper. In 1905, catches were reported from Chaik Bay and Hawk Inlet, but four of the localities mentioned in the reports of 1904 were not listed. In the next few years operations expanded, the catch increased, and more seines and traps were employed than ever before. This was followed by a period of regression which lasted two years, but 1911 marked the beginning of a rapid development of the industry and an invasion of new localities which culminated in 1917 in a level of production that has not since been closely approached. It does not follow, however, that this rather intensive fishing was more than the district could safely stand, although some areas may have been measurably depleted, for the catch remained comparatively high in all the years down through 1927, except in 1921, when operations were purposely curtailed. Even in the last four years, with a new law in effect, closed seasons and closed areas established, the catch still maintained a satisfactorily high level commensurable with the known productive strength of the district. This was the situation in regard to all species collectively. Looking at the data for each species separately, it is apparent that the only serious decline has been in the catch of chums, yet it can not be said definitely that this species was in fact less abundant than a decade before. The closed seasons could very easily have reduced the catch in greater proportion than they affected the other species, particularly in those local-

ities where the chums run later than the pinks. Of equal importance in this connection is the fact that the catches from 1921 to 1927 were made with fewer seines and traps than were operated in the preceding years of intensive fishing. Some places in the district show signs of depletion of certain species, as for example, Basket Bay in reds, and Chaik, Kelp, and Sitkoh Bay, and Tenakee Inlet in all species; but aside from these localities there are no definite signs of weakness in the runs of any species. The salmon fisheries of the northern part of the strait, therefore, may be regarded as having held their strength against the exploitation to which they were subjected.

The southern part of the Chatham Strait district includes 12 localities, equally divided between the Kuiu Island and Baranof Island shores, which have produced several thousand salmon of all species through many years, while the strait itself produced yet other large numbers of salmon. The history of its fisheries is similar in some respects to that of the northern part in that it dates from 1892 and shows the exploitation of the runs of red and coho salmon at Gut Bay, Bay of Pillars, and Tebenkof Bay, in the same manner as the red salmon streams of the northern section were fished. Not until 10 years later was any serious effort made to utilize other species, but beginning in 1902, pink salmon were taken and in a few years they became the most important fishery product of the district. The six localities on the Baranof shore are small bays which support insignificant runs of salmon and are fished by seines mainly for the reds that come to these streams, Port Walter and Patterson Bay being the exceptions. Fishing at these localities and at Port Herbert and Falls Creek Bay began much later than it did at Gut Bay and Red Bluff Bay, and it was apparently very irregular as the catch data show intervals of two and three years in which no salmon were taken. Even if these bays were fished each year and the catches allocated only to Chatham Strait, the fact remains indisputable that there are no important fisheries on the east shore of Baranof Island south of Kelp Bay. On the other hand the west shore of Kuiu Island constitutes the most productive field in the southern section of the strait, especially the north shore of Tebenkof Bay and the shore between Washington Bay and Kingsmill Point; but with this difference that the runs at these places are not necessarily local whereas those on the opposite side of Chatham Strait are strictly so. The large catches in both places were made by traps, and while the catches at Tebenkof Bay probably include some salmon that were bound to the streams of that bay, they also with equal probability contained large numbers of salmon that were destined to more northerly waters. The configuration of the shore at this point is such as to lead the runs into the bay before they round Point Ellis and continue their northward journey. It was possible, therefore, for traps on this shore to reach these deflected bodies of salmon and make large catches before the migrating fish left the bay. Salmon taken along Kingsmill beach are also largely moving to more distant localities, chiefly in the Frederick Sound district, a fact that was fully demonstrated by tagging experiments in 1924 and 1925. The Bay of Pillars runs, of course, are not touched by traps at Kingsmill as it is not likely that they compose any part of the migration north of Point Sullivan.

Bay of Pillars was one of the first localities to be fished in the southern part of Chatham Strait, solely for the reason that a tributary of the south arm supported a run of red salmon. It was a steady producer from 1892 to 1924, but after this arm was closed in 1925, due to the evident exhaustion of the run, very few red salmon have since been reported from Bay of Pillars. The falling off in the catch of other species, except chums, is also very evident as the total take of salmon in this bay in 1927 was only 4,455.

Gedney Harbor, Port Malmesbury, and Washington Bay have been uncertain producers but the catches are not materially less in late years than they were when the localities were first fished.

The maximum fishing effort in the southern part of Chatham Strait was reached in the four years from 1917 to 1920 as more seines and traps were used in those years than in any other period of the history of these fisheries. The largest catches of all species, except kings, were made in these years. Viewing the district as a whole, there has been no marked reduction in catches during the period covered by this report, except possibly in the case of red salmon which is probably, in part, the result of the closing of practically every red salmon stream in the district. In addition to the south arm of Bay of Pillars, other closures in 1926 included Gut Bay, Red Bluff Bay and Falls Creek, and the north arm of Tebenkof Bay which is now known as Elena Bay. The catch of chums and pinks was considerably less in later years than it had been for some time, possibly indicating depletion, although allowance should be made for the effect of closed seasons and limitation of fishing appliances on the catch. The runs of pink salmon in this section of the strait, as indicated by the catches, were marked by a peculiar oscillation in that during the earliest years of fishing the largest catches were made in the even years. This period was followed by another period, of 10 years or five cycles, 1908 to 1917, when the odd years were the most productive, which in turn gave way to a reversal of conditions whereby the even years again became the largest producers. The cause of these variations in the cyclic movements of this species is not explainable in the light of available data.

The catch of coho and king salmon continued to be large, that of cohos in 1927 being exceeded but four times in the 35 years that have elapsed since fishing began, and that of kings but three times in the 17 years which cover the history of the king-salmon fishery in this district. The catch of these species was rather insignificant until trollers discovered that the southern part of the strait was an important feeding ground of both kings and cohos, the most productive areas being at the junction of Frederick Sound and Chatham Strait and at Cape Ommaney. Hundreds of trollers resorted to these regions and made phenomenal catches of salmon. They fished for years without the slightest regard for the fishery laws and regulations, assuming that line fishing was not subject to the provisions of the law of 1906. This erroneous idea was exploded in 1923 by the conviction of certain trollers for fishing during the weekly closed season, and since then this type of fishing has conformed in general to the usual regulations. Just what effect this may have in the intensity of troll fishing is rather doubtful—it is at least possible that the actual reduction in intensity is very slight. If the catches were made only in the migration season while the salmon were on their way to the streams instead of generally throughout the year, weekly closed seasons would be of unquestioned benefit in making possible a better escapement than would otherwise result. But where line fishing is prosecuted on the feeding grounds which are populated with salmon as long as food is available, a weekly closed season of a few hours is by no means as certainly an effective measure of conservation.

Table 5 shows the catch of king and coho salmon by lines in the Chatham Strait district. These data are also included in the totals of Table 4.

Figures 18, 19, 20, 21, and 22 show graphically the catch of each species of salmon in the Chatham Strait district. An extremely high peak in production was reached suddenly in respect of each species except reds, that for pinks occurring in 1917, for chums in 1918, for cohos in 1919, and for kings in 1924, but in each case there was an equally rapid drop to normal levels. As has been so frequently noted in this review,

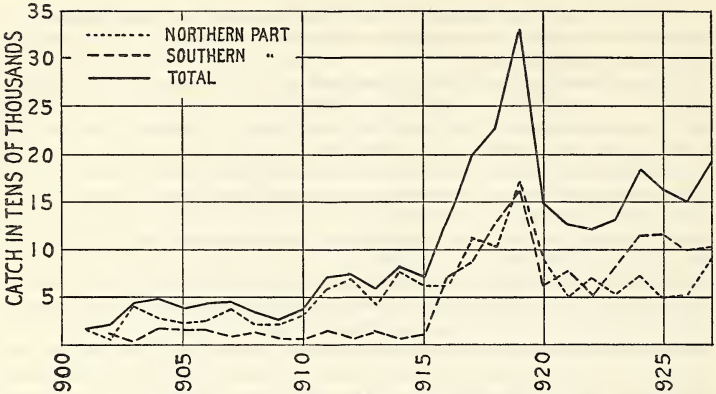

FIGURE 18.—Catch of cohos salmon in the Chatham Strait district, 1900 to 1927.

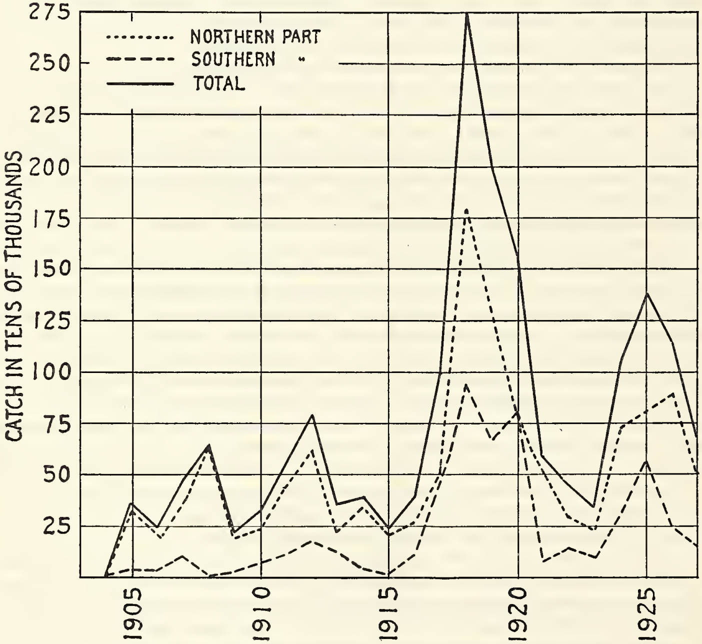

FIGURE 19.—Catch of chum salmon in the Chatham Strait district, 1904 to 1927.

catches were noticeably lower during the years from 1920 to 1923 immediately following the period of intensive fishing and inflated prices for both raw and canned salmon.

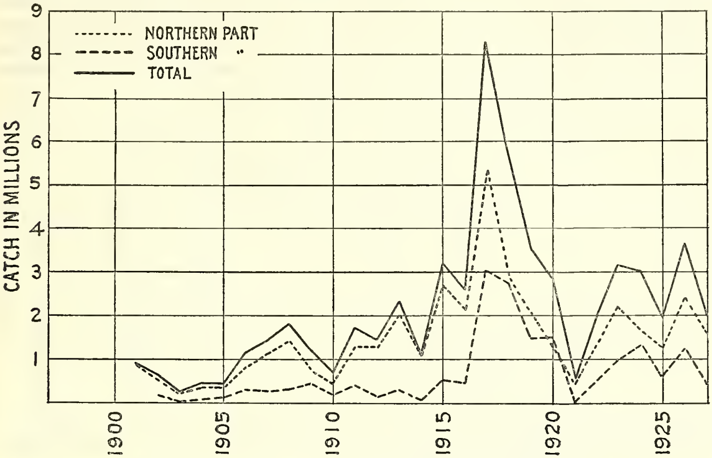

FIGURE 20.—Catch of pink salmon in the Chatham Strait district, 1901 to 1927.

Disregarding these extremes, as representative of abnormal conditions, it is apparent that there was little or no change in the trend of the catches for the decade or more

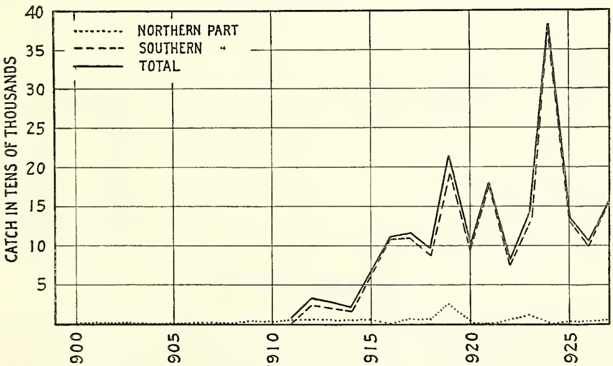

FIGURE 21.—Catch of king salmon in the Chatham Strait district, 1900 to 1927.

just preceding 1927. The graph illustrating the catch of red salmon is interesting in that the trend held a steady upward slope from 1900 until 1921, when it dropped sharply, due to the very limited fishing of that year. The catch improved again in

the next four years but fell off slightly in 1926, and in 1927 it declined more abruptly, touching a point that had been reached but twice in 27 years. This change is traceable to the effect of the regulations which closed areas about the mouths of the most productive red-salmon streams in the district, and may bear no relation to the scarcity or abundance of red salmon at these localities. It is at least possible that, had these regulations not been imposed, the catch of red salmon would quickly have reached

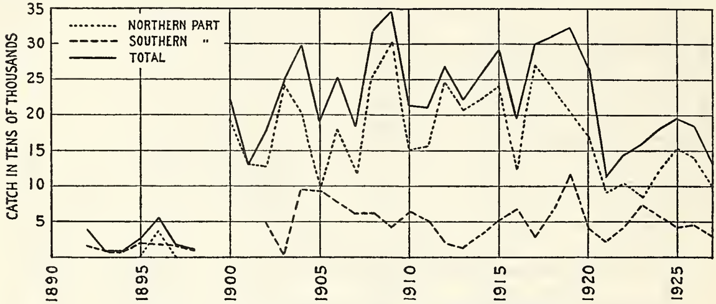

FIGURE 22.—Catch of red salmon in the Chatham Strait district, 1890 to 1927.

the level it had maintained through many years, although how much longer that level could have been maintained is problematical.

TABLE 5.—*Salmon caught by lines in the Chatham Strait district, 1911 to 1927*

Year	Northern part		Southern part		Total	
	Coho	King	Coho	King	Coho	King
1911				3, 274		3, 274
1912			74	24, 941	24	24, 941
1913		152		21, 499		21, 651
1914			614	16, 614	614	16, 614
1915			3, 401	58, 313	3, 401	58, 313
1916	1, 161	154	40, 408	107, 052	41, 569	107, 206
1917	4, 054	794	67, 937	109, 852	71, 991	110, 646
1918		1, 999	85, 933	86, 845	85, 933	88, 844
1919	1, 284	18, 947	97, 789	189, 097	99, 073	208, 044
1920			18, 750	89, 459	18, 750	89, 459
1921		441	58, 673	174, 366	58, 673	174, 807
1922		4, 571	25, 684	74, 452	25, 684	79, 023
1923		410	35, 668	127, 797	35, 668	128, 207
1924	259		44, 116	373, 427	44, 375	373, 427
1925	2, 478	1, 861	78, 568	131, 457	81, 046	133, 318
1926	4, 543	858	73, 963	97, 845	78, 506	98, 703
1927	15, 124	3, 498	39, 731	144, 124	54, 855	147, 622

FREDERICK SOUND

The Frederick Sound district covers the waters of southeastern Alaska east of a line from Point Gardner, the southern extremity of Admiralty Island, to Point Kingsmill on the northwest coast of Kuiu Island and south of a line from Point Pybus to Cape Fanshaw eastward to the north mouth of Stikine River and the south end of Dry Strait, together with all the waters of Keku Strait and Wrangell Narrows north

of 56° 40′ north latitude. Within these boundaries are several bays on the southern coast of Admiralty Island, the northern coast of Kuiu and Kupreanof Islands, and yet others on the mainland between Cape Fanshaw and Stikine River. (See fig. 23.)

The district contains no outstanding salmon streams and no exceptionally large catches have ever been reported from any particular locality, although in the aggregate a few seasons have produced much more than the general average for the period here considered. With few exceptions the larger catches were made by traps distributed along the shores of Admiralty and Kuiu Islands. Catches reported from the bays were made largely by seines.

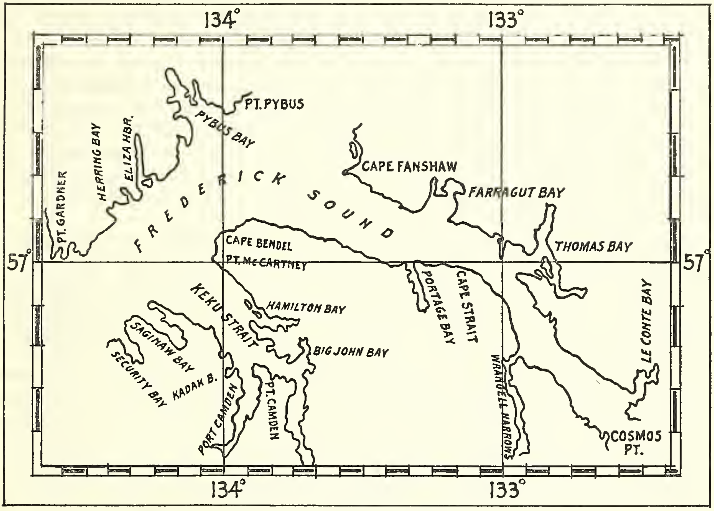

FIGURE 23.—Map of the Frederick Sound district.

Salmon canning in this district commenced in 1900 at a plant on Wrangell Narrows where the town of Petersburg is now located. In 1901 another cannery was established on Wrangell Narrows about 10 miles south of Petersburg. A saltery was opened in the same year at Ideal Cove in Dry Strait near the north mouth of Stikine River. Records of the catch of salmon by these packers do not show the localities in which the fish were caught, although Kutchin, in the Treasury reports for the years 1900, 1901, 1902, and 1903, gives the total number of salmon utilized by each company. Presumably some of these catches were made in the Frederick Sound district, and it is equally probable that some were made in the Sumner Strait district as the plants were located near the boundary of the two districts. No allocation of these catches is attempted, but in order to make the fullest use of available data, they are shown in the following table.

TABLE 6.—*Catch of salmon in the Frederick Sound district, 1900 to 1903*

Year	Coho	Pink	King	Red
1900	15,000	400,000		140,000
1901	38,000	1,007,000	5,269	194,000
1902	1,157	686,836	3,793	110,961
1903	44,364	77,078	181	69,162

Beginning with 1904 and continuing through 1927 all data were taken from formal reports of the operators, but in this district, as in all others of southeastern Alaska, catches from entirely different bodies of water, often widely separated, were frequently combined and reported under a locality name embracing waters in two or more districts. The use of such data necessitated a somewhat arbitrary division of these catches in order that the real value of each district as a salmon-producing area might be shown. The only alternative was to show them as unallocated catches of southeastern Alaska and thus defeat to some extent the object of segregating the data of recognized fishery districts. There were also several catches from localities which have no geographic identification, which of necessity were included in the unallocated totals. A confusion of names was likewise encountered, but in most cases it was possible to make satisfactory corrections. All of these changes will be indicated in the discussion of the data for the different localities.

The catch of salmon in the Frederick Sound district from 1904 to 1927 is shown in tables 7 and 8. Along the Admiralty Island shore between Point Gardner and Point Pybus are nine localities from which fair catches of salmon, mostly pinks and chums, have been taken. Of these, Murder Cove, Carroll Island, Point Brightman, Point Napean, Deepwater Point, Pybus Reef, and Point Pybus were trap locations, those nearer the western entrance of the sound producing the larger number of salmon. The more northerly locations were distinctly less productive, yet the intervening bays, three in number and known as Herring Bay, Eliza Harbor, and Pybus Bay, especially the latter, show catches comparable in size to those of the localities near the western entrance. The data for Pybus Bay, which includes catches from Little Pybus Bay in 1926 and from "Pipers" Bay in 1920 and 1923, indicate that this bay leads all other localities on the Admiralty shore in the production of pinks and chums. Its several streams probably constitute the best spawning areas on the north side of Frederick Sound. Large catches were made in the period of heavy exploitation from 1917 to 1920 and do not show the cyclic fluctuations which were decidedly conspicuous after 1923. The catch of all species in 1927, however, was the smallest reported from Pybus Bay in 10 years and doubtless was due to a scarcity of salmon.

Notwithstanding the occasional poor catches, data for this section of the sound show no definite evidence of depletion of the runs. The trend of the catch since 1920 has been upward and shows no indication of changing in the near future.

TABLE 7.—*Salmon catch and fishing appliances used in the Frederick Sound district, 1904 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Bay Point:												
1920	807	10,876	33,169		996							
1921	505	6,097	11,213	363	1,163							
1922	960	3,644	29,933	18	2,278							
1923	1,538	3,339	22,316	43	3,286							
1924	306	10,282	45,034	12	2,165							
1927	181	1,272	6,734		395							
Bendel, Cape:												
1915	508	6,956	248,699		1,245							
1917	80	1,366	70,340		50							
1920	35	3,316	7,309	3	82							
1922	1	66	2,384		1							
1924	2,523	14,912	189,715	41	3,093							
1925	549	14,992	27,232	16	946							
1926	1,043	15,889	176,959		2,982							
1927	372	838	4,782		66							
Big Johns Bay:												
1915		613	9,420									
1919	13	2,322	2,786									
1923	24	1,640	1,207		1							
1924	139	26,822	12,381									
1925	5	12,254	2,431									
1926	103	21,994	44,551		5							
1927		2,575	23									
Boulder Point:												
1927	1,150	2,300	6,780	36	2,041							
Brightman, Point:												
1919	562	11,791	10,985		367							
1921	1,161	18,634	12,316	22	380							
1922	1,821	6,133	55,310	7	1,405							
1923	2,370	8,781	90,060		1,297							
1924	1,196	5,836	159,300		789							
1927	4,509	7,785	22,637		745							
Brown Cove:												
1919	1,116	7,756	9,730	26	947							
1922		372	22									
1924		234	2		1							
1925	14	4,468	1,549		1							
Camden, Port:												
1905		75,000										
1906		49,273										
1907		19,656	3,963									
1908	1,598	80,704										
1909	405	5,993	5,892									
1911	177	9,135	4									
1912	39	1,833										
1913	38	30,325	22									
1915		13,827	108,620									
1916	8	62,457	3,940									
1917			2,268									
1918	217	15,376										
1919	432	12,983	1,270		1							
1920	179	41,211	1,760		2							
1922	646	27,179	2,257									
1923		3,043	7									
1924	67	28,976	2,100									
1925	1,216	105,100	2,492		97							
1926	1,188	40,992	13,923									
Carroll Island:												
1926	831	8,481	84,710		978							
1927	1,050	4,696	5,913	33	4							
Deepwater Point:												
1919	209	8,334	11,444		614							
1927	754	2,197	9,997	50	409							
Eliza Harbor:												
1915		4,473	40,311									
1917	19	7,434	84,454		3							
1919	3	2,200	1,205	1	1							
1920		714	181		1							
1922		400	970									
1923	40	217	1,752									
1924		5,006	4,324		1							
1925		689	93									
1926		4,257	2,865									
1927		820	2		1							
Fanshaw, Cape:												
1913				625								
1917		1,202	39,057	3	144							
1918		3,268	2,679									
1919	247	1,910	11,951		317							
1924	1,130	4,940	52,942	40	1,165							
1925	566	6,971	16,452	12	761							
1926	1,607	18,748	148,679	2	3,744							
1927	888	3,430	26,419	82	1,009							

TABLE 7.—*Salmon catch and fishing appliances used in the Frederick Sound district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Farragut Bay:												
1911		177	230									
1912	676		2, 689									
1916					1, 286							
1917	25	321	10, 826		5							
1918		200										
1919		2, 756	2, 260		19							
1920			2, 373									
1921			238		298							
1922			13		549							
1924		162	3, 865									
1926		12, 613	5, 537		165							
Five Mile Creek:												
1923	6	43	2, 240		57							
1924	3	7	7, 294		3							
1926		160	164		17							
Hamilton Bay:												
1904	805	6, 500										
1908	7, 532	258										
1911	1, 633	444	67, 121									
1914	2, 560											
1915	6, 998	8, 827	19, 428									
1916	7, 963	25, 738	55, 475		8							
1917	2, 459	12	164									
1918	129											
1919	37	3, 127	3, 884		203							
1920	16	3, 110	667		11							
1922	4, 488	13, 785	20, 631		1							
1923	2, 591	2, 522	4, 650									
1924	999	25, 786	26, 614	780	8							
1925	42	28, 654	2, 784		1							
1926	1, 956	9, 407	77, 077		15							
Herring Bay:												
1917	666	32, 346	194, 500	43	414							
1918		11, 495	16, 479		3							
1919	159	14, 362	10, 185		411							
1924		4, 001	3, 120		1							
1925	12	1, 873	100									
1926		509	2, 163									
1927	1, 367	3, 463	7, 676	42	423							
Highland, Point:												
1919	1, 057	10, 272	19, 993		2, 394							
1922		18	669									
1923	231	838	11, 703		354							
1924	593	5, 832	125, 844		383							
1925	438	3, 211	7, 539		433							
1926	456	5, 595	41, 117		628							
1927	790	3, 872	22, 609	77	740							
Ideal Cove:												
1916		6	2, 730		6							
1918	1	579	7, 042		78							
1922	1	23	929									
1924	8	2	294									
Kadakes Bay:												
1913	3	1, 645	11, 886									
1914	1, 000											
1922	186	534	9, 191									
1923	505	3, 110	7, 358									
1924	124	8, 732	64, 657		373							
1925		2, 379	1, 219									
1926	1, 357	12, 614	69, 244		1							
1927	8	2, 786	4, 314		6							
Keku Strait, north end:												
1904	17, 000											
1905	10, 000	7, 000										
1906	6, 000											
1907	5, 000											
1908	9, 500											
1909				7, 044								
1914		50, 000	25, 000									
1915	225	2, 647	89, 362									
1916	1, 758											
1917	3, 088	9, 258	63, 700									
1918			11, 000									
1919	391	4, 486	1, 478									
1920	810	4, 757	2, 835	2	67							
1921		11, 411	1, 853									
1922	1, 754	45, 252	48, 735		69							
1923	896	15, 380	134, 067		1, 527							
1924	1, 062	58, 542	62, 842		96							
1925	876	64, 863	15, 223		50							
1926	887	57, 319	210, 178		222							
1927	126	17, 370	2, 227		108							

TABLE 7.—*Salmon catch and fishing appliances used in the Frederick Sound district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Macartney, Point:												
1919	310	2,864	2,963		219							
1924	1,383	10,357	127,922	7	869							
1925	565	8,256	21,350		560							
1926	477	12,990	66,301		541							
1927	2,320	6,883	44,259	101	647							
Murder Cove:												
1908		20,000										
1912	1,528	6,250	604									
1913	144											
1914		1,035	201									
1915			8,775									
1916		1,565										
1917		8,000	20,000									
1918	5,698	17,462	5,311	4,748	349							
1919	2,716	86,810	71,689	160	3,270							
1920	795	53,541	50,196	45	2,380							
1921		2,595	565									
1924	3,426	29,262	203,621	12	3,493							
1925	2,940	31,659	36,228	15	1,635							
1926	1	888	378									
1927			269									
Napean, Point:												
1919	189	2,778	4,211	7	92							
1920	267	9,861	16,664	2	239							
1926	705	11,252	71,075		553							
1927	775	5,493	4,579		6							
Petersburg Creek:												
1904	4,256		48,752	5	661							
1905	1,724		64,249		1,892							
1906	1,876	8,064	51,017		2,721							
1907	3,912	11,213	71,997		634							
1908	2,205	23,210	101,852	100	805							
1909	1,434	17,862	52,666		3,427							
1910	3,828	5,798	28,394		268							
1911	2,922	1,368	13,723		215							
1912	1,604	3,135	24,853									
1916	580	6,338	123,122	1	736							
1917	1,922	7,386	137,972		1,162							
1918	570	27,404	108,308		2,633							
1920	944	5,222	23,972		510							
1921					52							
1922	287	1,380	2,837		1,912							
1923	117	5,241	11,312		2,567							
1924	668	1,717	63,148		481							
Portage Bay:												
1904	3,856		3,145		8							
1908			15,000									
1910		976	5,626	167	26							
1912	97	4,064	18,582		20							
1914	3,180											
1917	1,158	741	19,878		1							
1918		10,454	30,316		4							
1920	111											
1922		4,629	3,370									
1923	1	939	704									
1924	483	8,131	23,324		9							
1925	19	15,824	2,630									
Pybus Bay:												
1907		25,819										
1912	128	69,983	27,809	4	197							
1915		22,703	110,621									
1916		5,675										
1917	1,532	57,659	403,185	3	4							
1918	858	194,083	348,346	2	69							
1919	999	169,237	55,705	1	1,109							
1920	219	100,460	9,583	7	160							
1921	3	10,955	5,174		54							
1922	251	7,736	18,697		20							
1923	4	2,806	6,774									
1924	228	66,801	75,496		408							
1925	8	21,291	3,803		3							
1926	2,777	113,505	515,428	29	6,444							
1927	1	6,215	653		2							
Pybus, Point:												
1924	3,238	2,022	50,621	42	3,209							
1925	994	17,924	21,529	43	994							
1927	1,449	4,538	15,181	100	538							
Pybus Reef:												
1925	1,122	24,425	31,088	73	1,280							
1926	330	11,766	91,372	6	760							
1927	263	419	1,522		11							

TABLE 7.—*Salmon catch and fishing appliances used in the Frederick Sound district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Saginaw Bay:												
1904		22,500										
1905	9,000	75,000										
1906	8,087	113,729										
1907		78,485	86,774									
1908	10	8,121	378,391									
1910		13,361	34,145									
1911		30,701	48,242									
1912		77,726	39,805		9							
1913	1	1,608	2,444									
1914		25,000	10,271		75							
1915		3,417	108,581									
1916	3	4,160	1,376		3							
1917	2	30,334	89,420		165							
1918	1	18,414	23,799		72							
1919	700	24,649	28,079	5	441							
1920	466	19,150	48,153	16	850							
1922	63	4,102	30,138									
1923	50	3,722	16,379		637							
1926	1,679	11,032	169,513	534	1,839							
1927	1,435	4,358	14,392	43	285							
Security Bay:												
1905		82,000										
1907	2,631	9,997										
1908		25,000	60,000									
1910		42,583	129,000									
1911		137,999	107,536									
1912	912	10,714										
1913		1,137	1,052									
1914	2,001	17,849	13,823	3,000								
1915		1,876	41,800	447	4							
1916	7,326	24,720	94,360		3,783							
1917	4,357	53,227	88,690		200							
1918	2,089	70,173	45,800	1	6							
1919	327	23,248	16,053									
1920		13,121	10,083		22							
1922	183	1,075	2,795		103							
1923	71	4,346	16,204		750							
1924	756	41,296	22,706	21,410	2,210							
1925	1,385	96,628	21,116	6	539							
1926	10,934	27,668	223,630	4,295	3,824							
1927	12,729	18,816	58,486	217	2,191							
Strait, Cape:												
1915			22,400									
1917			7,360									
1920			6,582									
1924	1	17	5,722		3							
1926	219	3,896	26,996		68							
1927	195	1,312	1,267		3							
Thomas Bay:												
1917			14,455									
1918	20	90	7,685	1	4,552							
1926		4,753	1,309									
1927		487										
Unallocated:												
1904			7,500									
1905		52,452	17,765		1,947							
1906		60,225	43,393		5,622							
1907		83,051	55,684		4,694							
1908	5,342			8,661								
1909	1,069	44,750	33,533	11,777	16,141							
1910		82,710	26,120	12,873	8,721							
1911		108,248	186,792	2,850	4,596							
1912	9,001	235,064	368,784	15,174	15,107							
1913	3,396	99,860	457,070	158	10,728							
1914	12,699	89,705	279,842	936	14,667							
1915	9,582	74,899	860,253	3,893	18,917							
1916	13,794	105,099	909,212		22,067							
1917	5,031	144,764	1,382,538	449	12,532							
1918	14,719	627,034	2,277,908	148	10,220							
1919	17,843	485,724	493,284	69	13,733							
1920	37,197	297,501	1,001,512	3,012	41,143							
1921	39,786	92,686	375,979	5,481	14,151							
1922	3,852	53,315	200,555	41	2,556							
1923	24,229	68,409	568,332	5,447	14,153							
1924	5,755	38,141	281,863	21	5,425							
1925	15,865	153,442	197,604	12,134	5,040							
1926	17,513	137,636	724,999	150	14,422							
1927	5,501	14,234	59,994	1,899	3,255							
Total:												
1904	25,917	29,000	59,397	5	669			8		10		
1905	20,724	291,452	82,014		3,839	3		8		8		
1906	15,963	231,291	94,410		8,343	2		7		10		
1907	11,543	228,221	218,418		5,328	3	200	12	1,775	3	120	

TABLE 7.—*Salmon catch and fishing appliances used in the Frederick Sound district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Total—Continued.												
1908	26, 187	157, 293	555, 243	8, 761	805	4	400	21	3, 470			
1909	2, 908	68, 605	92, 091	18, 821	19, 568			4	700			
1910	3, 828	145, 428	223, 285	13, 040	9, 015			6	1, 050			
1911	4, 732	288, 072	423, 648	2, 850	4, 811	15	2, 360	6	975	2	60	2
1912	13, 985	408, 769	483, 126	15, 178	15, 333	3	285	28	5, 430	2	200	4
1913	3, 582	134, 575	472, 474	783	10, 728			10	1, 550	1	175	6
1914	21, 440	183, 589	329, 137	3, 936	14, 742			18	3, 670		175	4
1915	17, 313	140, 238	1, 668, 270	4, 340	20, 166			19	2, 890			7
1916	31, 432	235, 758	1, 190, 215	1	27, 889	4	260	23	4, 038			6
1917	20, 339	354, 050	2, 628, 807	498	14, 680	1	100	60	9, 555	3	325	11
1918	24, 302	996, 032	2, 884, 673	4, 900	17, 986	20	2, 708	54	10, 070	6	480	10
1919	27, 310	877, 609	759, 155	269	24, 138	24	3, 440	51	10, 020			16
1920	41, 846	562, 830	1, 215, 039	3, 087	46, 463	17	2, 825	33	6, 380	2	100	24
1921	41, 455	142, 378	407, 338	5, 866	16, 098	4	405	13	2, 550			8
1922	14, 493	169, 643	429, 436	66	8, 894			19	3, 275			11
1923	32, 673	124, 376	895, 065	5, 490	24, 629			28	4, 125			18
1924	24, 088	397, 816	1, 614, 751	22, 365	24, 185			48	7, 965			14
1925	26, 616	614, 903	412, 462	12, 299	12, 340			44	7, 305			19
1926	44, 063	543, 964	2, 768, 168	5, 016	37, 208			40	6, 855			18
1927	35, 863	116, 159	320, 715	2, 680	12, 885			15	2, 670			17

NOTE.—No catch was reported in the years omitted from the several divisions of this table.

TABLE 8.—*Catch of coho and king salmon in the Frederick Sound district, by lines, 1908 to 1927*

[Included in table 7]

Year	Coho	King	Year	Coho	King
1908	1, 329	8, 661	1917	1, 928	
1909	19	12, 973	1918	5, 698	4, 748
1910		12, 873	1921	40	2, 950
1911		2, 850	1923	1, 483	4, 903
1912		15, 000	1924	69	22, 190
1913	625		1925	7, 130	12, 091
1914	4, 066	14, 319	1926	16, 247	10, 747
1915	50	3, 547	1927	6, 950	1, 925

The mainland shore of Frederick Sound has no important fishery. Traps operated between Cape Fanshaw and Bay Point made fair catches in some years, but Brown Cove, Farragut, and Thomas Bay were less productive.

The Mitkof and Kupreanof Islands shores are also relatively unimportant. No streams of consequence are located in these sections, except possibly Petersburg Creek which was fished heavily for several years until the runs were nearly destroyed. This was stopped by the regulations in 1924 and has not since recurred. Traps in the vicinity of Cape Bendel and Point Macartney made good catches, but those at Boulder Point and Cape Strait were poor producers. Even if a part of the catches reported from Portage Bay came from the trap at Boulder Point, which is likely, the situation would not be materially changed. The remaining localities in this part of the sound, namely, Ideal Cove and Five Mile Creek, are relatively unimportant. According to available statistics, fishing was limited to a few seasons and catches were small. Perhaps, however, both localities were fished more regularly than the records show, the catches being reported as from the sound without more definite allocation. It is also probable that a considerable number of salmon were taken from Five Mile Creek by fox farmers on the adjacent Sukoi Islets, of which no record was kept.

Next to the Admiralty shore, the bays on the northwest shore of Kuiu Island and those tributary to the northern part of Keku Strait constitute the most productive section of Frederick Sound. Several fairly large streams entering these bays support good runs of pinks and chums, particularly Security, Saginaw, Kadakes, Hamilton, and Big Johns Bays. The catch in Keku Strait proper also reached sizable proportions, disregarding the possibility of faulty allocation as many of the salmon reported as taken in the strait may well have come from the bays just named. The strait and its bays are fished largely by seines so that it is more than probable that much of the fishing was carried on near the streams and therefore in the bays, as few streams, if any, debouch directly into the strait. The catches in this locality include salmon reported from Keku Islet in 1926 and from Kake Harbor in 1926 and 1927. They also include part of the unallocated catch from Keku Strait and Frederick Sound in 1912 and part from "Frederick Sound, Keku and Chatham Straits" in 1913. It was also necessary to divide the Keku Strait catches between the northern and southern parts of the strait as the southern section is included in the Sumner Strait district. This division affects the data for the years 1904 to 1908, 1912, and 1914 to 1927. The catch at Port Camden in 1926 was increased by the addition of salmon reported in that year from Port "Compton"—a corruption of the correct name. The total for Kadakes Bay was augmented by the inclusion of fish reported from "Kardake Bay" in 1913.

Security Bay and Saginaw Bay both show rather steady production of pinks and chums through 20 years. The larger catches in some years may be accounted for in the operation of traps at the entrance of the bays, but seine fishing was also successfully carried on in these waters. The catch in Saginaw Bay was increased by the inclusion of part of the salmon reported from Saginaw Bay and Chatham Strait in 1912, and that in Security Bay by a division of the salmon reported from Pleasant Bay and Security Bay in 1918.

The unallocated catch in Frederick Sound reached comparatively large totals in several years, due to the failure of the operators to give more exact information as to the places where the salmon were caught. In other cases where definite allocations were made, the catches were small or fishing was not continuous. As no worthwhile purpose could be served in treating them separately, they were included in the unallocated catches of the sound. Catches from the following localities were so treated: Beacon Point, Meade Point, and Harbor Bay in 1925; Meade Point, Cyrus Catt Creek, and Petersburg in 1918; Kupreanof in 1920; Le Conte Bay in 1917 and 1927; Muddy River and Kasheen Bay in 1926; Point Gardner in 1917, 1919, 1920, and 1927; Horigan Point in 1924; Kjeen Bay and Point Kingston in 1912; Donkey Bay in 1927; and Elliott Island in 1924. It was also necessary to divide certain catches reported under the following locality names: "Frederick Sound, Stephens Passage, and Sumner Strait" in 1923; "Icy, Chatham, and Peril Straits and Bays" in 1905 to 1907 and from 1909 to 1919; "Icy Strait and Frederick Sound" in 1918 to 1921; "Keku Strait and Frederick Sound" in 1912; "Kake and Seymour Canal" in 1916; "Frederick Sound, Keku and Chatham Straits and tributaries" in 1913; "Chatham Strait, Frederick Sound, and Stephens Passage" in 1923; "Chatham Strait and Frederick Sound" in 1919; "Frederick Sound, Stephens Passage, and Sumner Strait" in 1923; "Sumner Strait and Frederick Sound" in 1914 and 1920; and "Admiralty Island" in 1919, 1920, and 1924. As was explained in the discussion of other districts and as will be done in reviewing the data for yet other districts, these divisions were based upon the best available information regarding the field of operations of the

packers using such faulty allocations. It is recognized, of course, that general allocations of this kind are made at the expense of other definite localities, the returns from which are therefore lowered.

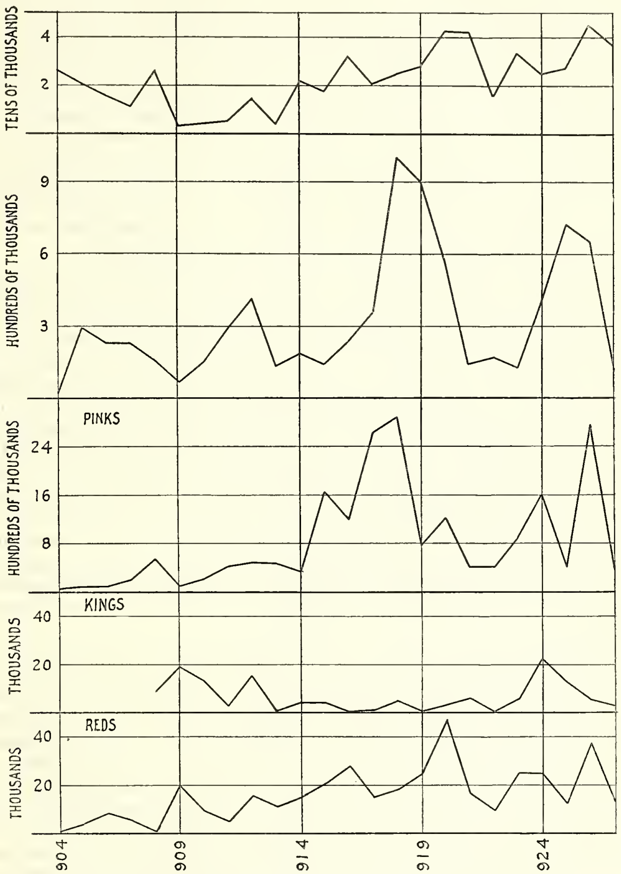

FIGURE 24.—Catch of salmon in the Frederick Sound district, 1904 to 1927.

The total catch of salmon in the Frederick Sound district is shown graphically in figure 24.

Figure 24 shows that the production of cohos has been fairly constant since about 1914 which ended a 5-year period of small catches, and that the number taken in 1926

exceeded the catch in all other years covered by this review. The fact that this was accomplished under more stringent regulation of fishing than had ever before prevailed makes it seem very probable that no depletion of this species has occurred.

The condition of the chum fishery appears less satisfactory as the catches since the economic drop in 1921–1923 have not fully recovered and are still but slightly higher than those of the poor years almost a decade earlier when fishing was far less intensive and when only a few packing plants were in operation. If it were not for the greater restriction of fishing in these later years, there would be reason to assume that the chum fisheries show depletion, especially when viewed in the light of the larger number of seines and traps now in use. The changed regulation of fishing in 1924 and the slackened fishing effort in the few years just preceding upset the continuity of operations and leave no satisfactory basis for an appraisal of the present condition of the fishery. The reported catch of only 116,159 chums in 1927 probably is indicative of a poor run in that year, since it represents a decline of more than 80 percent from the catches in 1925 and 1926 and is the lowest catch on record since 1909.

The development of the pink-salmon fishery was marked by no very large catches until 1915 when 1,668,270 pinks were caught, exceeding by more than 1,000,000 the catch in any earlier year. That was the beginning of a 4-year period of large production which reached a high point in 1918 when 2,800,945 pinks were taken. The decline in the fishing effort of 1919, caused by overproduction in 1917 and 1918, was reflected in the drop of 73 percent in catch in that year. The catch in 1920 was 38 percent larger than in 1919, but it was followed by a decline of 65 percent in 1921, from which there was practically no recovery in 1922. The curve of production moved upward in 1923 and 1924, only to fall to very low levels in 1925 and 1927 while the intervening year of 1926 showed a catch almost equal to that of 1918. Production in the even years increased more rapidly than it fell off in the odd years, but the fluctuations since 1922 indicate that the general conditions as regards the pink-salmon runs is none too stable. At the present rate of regression, the odd years will soon provide very poor runs in the Frederick Sound district. Drastic curtailment of fishing in 1927, by Executive orders, was necessary to provide even a moderate escapement, and the wide fluctuations in catches in recent years may presage a failing supply of pinks.

The king-salmon fishery of this district is not important. Fair catches were made in 5 years, perhaps largely as the result of trolling in the western part of the sound. As these catches were made in large part on the feeding grounds of the kings, they cannot be regarded as coming from runs to Frederick Sound. A few kings bound for the Stikine River may pass through this waterway, but the bulk of the Stikine run undoubtedly approaches the river through Sumner Strait and Clarence Strait. The Taku River may also account for some of the kings taken in the sound. The fact that a considerable part of the catch was taken by lines gives no indication that this district supports a run of kings distinctively its own. No streams tributary directly to the waters of the sound have ever been recognized as producers of king salmon.

The district is likewise poor in red-salmon streams. The largest catches ever reported from its waters were 46,463 in 1920 and 37,208 in 1926, while the average for 24 years is less than 20,000. They doubtless came chiefly from runs to other districts which may account for the absence of marked indications of depletion. There is little probability that larger catches of this species will ever be made in this district without a material increase in the number of traps along the migration routes of the incoming salmon.

STEPHENS PASSAGE

The Stephens Passage district covers all the waters of the mainland and the east coast of Admiralty Island between a line from Cape Fanshaw to Pybus Point northward to the southern boundary of the Lynn Canal district across Saginaw Channel from Point Retreat to the north end of Shelter Island and thence to a point on the mainland 2 miles north of Eagle River. (See fig. 25.)

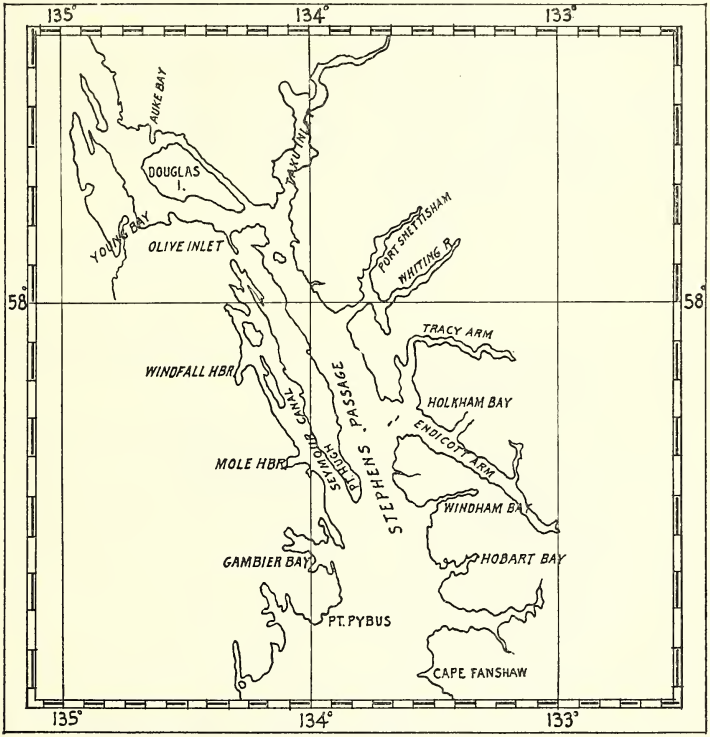

FIGURE 25.—Map of the Stephens Passage district.

The salmon fisheries of this district were first exploited about the time canneries were established on Chilkat Inlet, as catches of king and red salmon from Taku River, the most important stream in the Stephens Passage district, were utilized at those plants. No record of the number of salmon by species, or otherwise, which were taken from this river during the early years is now available, but the Chilkat canneries usually took about 3,500 cases of salmon annually from the Taku until canneries were opened in this district. In 1900, two canneries were built on Stephens Passage

to utilize Taku River salmon, although a saltery had been opened near the head of Taku Inlet in 1897 and operated a few years. During these early years fishery establishments changed hands frequently, and often were operated only one or two seasons, consequently reliable statistics of catches were not always obtained from the packers. All salmon which were taken in Taku Inlet and canned at Chilkat were probably recorded as Chilkat Inlet fish, and it is also likely that similar errors in allocation of catches occurred after the establishment of canneries near Taku, at least during the years that the Chilkat canneries drew on the Taku fisheries for a supply of salmon. Eventually this practice was discontinued.

Prior to 1904 packers were not required to make allocations of catches to definite streams or bays, so that no information is now available to show the source of supply of the salmon used in those earlier years, but in order to make the review as complete as possible by presenting all available data, a separate table, showing as unallocated catches the salmon probably caught in the Stephens Passage district before 1904, is given in table 9. It does not take into consideration the Stephens Passage salmon which were utilized outside of the district.

TABLE 9.—*Catch of salmon in the Stephens Passage district, 1900 to 1903* [1]

Year	Coho	Chum	Pink	King	Red
1900	16,292	30,180	93,881	22,653	117,878
1901	110,185		485,997	16,444	199,924
1902	42,802		587,979	22,300	264,917
1903	67,973		892,890	2,284	291,108

[1] The data for 1900 were obtained from Moser's pack figures, (1902, pp. 260 and 313), by reducing the number of cases reported by him to fish, using his average number of fish per case in making the calculations. Two companies were operating in this field. Moser's averages per case were as follows: Kings, 2.8 and 3; reds, 9; cohos, 7; pinks, 21; and chums, 6.5 and 7. The figures for other years were taken from the reports of the Treasury agents.

From 1904 to 1927 all data used in this report were obtained from formal reports of operators on file at the Bureau of Fisheries in Washington. In several cases catches in this district were combined with catches from other districts and so reported. A division as between districts, therefore, has been made somewhat arbitrarily but as fairly as possible in the light of all information now available, but allocation to definite bays or streams could not be made. Tables 10 and 11 show in detail the catch of salmon in this district. Catches from 26 localities have been given separately, and those from 21 unimportant or undetermined localities were merged with those indicated. Where catches were reported from two localities under one name, as "Pleasant Bay and Security Bay" divisions were made in accordance with our understanding of the extent of operations in each field by the operators concerned. Probably no other course could give a more satisfactory allocation of catches at this time. The only alternative would have been to throw all such catches in with the unallocated catches of the district; but, as in the case cited, where the joined localities were in different districts, this could not be done. It was also necessary in the case of some of the early years to make allocations to the district from the unallocated catches of southeastern Alaska as a whole, due to the failure of the operators to show localities at all. In such cases, allocations were made to the waters in the vicinity of the plants of the packers so reporting.

TABLE 10.—*Salmon caught and fishing appliances used in the Stephens Passage district, 1904 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Admiralty Cove:												
1926		8,009	1,295									
1927		1,617	12									
Auk Bay:												
1904	1,908	44,628	19,476		8,707							
1905	4,928	3,760			27,553							
1915	72	687	1,168		4,654							
1916	797	531	100		2,290							
1917	73	866	53		456							
1918		2,735	531									
1922	126											
1923	1	258	1,120		702							
1924	528	6,708	302		2,365							
1925	1	1,418	1		140							
1926	2	13,429	5,192		571							
Eagle River:												
1917	5	11,860	6,212		21							
1918	504	7,869	317		3							
1924		2,076	90		451							
1927	1	190	463		2							
False Point Pybus:												
1925		18,287	28,779	48	750							
Fanshaw Bay:												
1920		1	148									
1926	1,023	5,059	110,376		1,404							
Favorite Channel:												
1923	2,009	3,130	2,720		2,814							
1924	134	21,466	387		207							
Fritz Cove:												
1918	1,104	34,887										
1919	131	2,821	381		49							
1926		1,233										
Gambier Bay:												
1907			14,800									
1912	974	27,254	17,725		4							
1913	2		28,829									
1914		10,000	30,000									
1916	894	66,329	97,406		89							
1917	63	88,909	304,714	1	44							
1918	72	127,528	311,877	14	948							
1919	40	82,299	19,031		11							
1920	130	67,938	76,325		4							
1922	19	52,532	42,454		126							
1923	391	22,328	102,112		1							
1924	85	97,949	281,211	2	265							
1925	66	67,813	10,298	1	12							
1926	17	74,676	67,188		21							
1927		2,124	98									
Glass Point:												
1925		6,266	9,614	12	504							
Hobart Bay:												
1907			57,430									
1912		273	46,156									
1916	8	5,282	251,509		3							
1917	3	7,978	64,315	4	8							
1918	5	68,411	103,350	3	16							
1919	98	13,501	6,867	72	355							
1920	322	7,422	27,623	3	245							
1922	21	10,766	26,943		85							
1923		749	151									
1924	29	6,257	40,281		31							
1925		14,518	22,633	1	4							
1926	14	51,696	49,557		151							
1927	233	17,558	13,344		44							
Hobart, Point:												
1919	312	2,665	7,278	20	854							
1922	501	3,271	72,175	16	475							
1923	1,741	5,474	76,607	47	885							
1924	800	8,851	176,070		1,093							
1925	882	17,520	47,344		1,073							
1926	910	16,965	276,662		2,311							
1927	478	2,982	15,049	80	393							
Houghton, Port:												
1910	1,266											
1912	73	4,990	11,222									
1913			12,000									
1914		9,018	55,837									
1916	31	15,806	711,584	20	8							
1917	887	16,252	649,182	819	1,684							
1918	292	63,968	326,603	644	1,171							
1919	368	16,480	23,827	198	1,031							
1920	163	37,474	49,655	72	336							
1921	364	5,942	37,048	49	336							
1922	1,309	26,406	211,673	15	687							
1923	4,193	16,847	220,933	780	2,004							
1924	1,062	36,040	473,664	381	1,651							

TABLE 10.—*Salmon caught and fishing appliances used in the Stephens Passage district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Houghton, Port—Contd.												
1925	438	22,493	59,772		435							
1926	322	40,584	162,542		1,375							
1927	296	5,398	9,960	91	191							
Hugh, Point:												
1926	412	12,841	146,692		741							
Lena Cove:												
1905	500	4,000	3,250		3,000							
1912	36	9,417	3,040		2,873							
1920		109	490		371							
Limestone Inlet:												
1907			39,785									
1912		1,242	5,484									
1913		173	941									
1914		91	4,635									
1917		805	6,044									
1918	404	11,952	99,659		261							
1919	851	4,924			601							
1922			4,500									
1926	1	9,681	28,798		32							
1927	2	1,123	6,308									
Mole Harbor:												
1917		5,985	88,562		39							
1918	10	4,361	27,343	2	8							
1919	5	11,136	8,390		1							
1920		1,655	4,575									
1922		1,389	869									
1924	546	6,969	106,612		396							
1925	204	5,029	8,632		167							
1926	381	16,372	140,838	4	721							
1927	227	2,399	6,482	38	180							
Pleasant Bay:												
1904			23,035									
1905		20,800	30,000									
1908			6,080									
1912	86	834	954		1							
1913			3,000									
1914			7,690									
1915	438	23,362	243,709		195							
1916			8,446									
1917		554	12,426		16							
1918	347	10,179	8,925									
1920		479	2,790									
1927	272	2,475	8,427	41	177							
Saginaw Channel:												
1912	29,970	49,621	158,004	1,284	40,107							
1913	23,584	28,032	142,500	754	27,300							
1914	20,019	51,473	62,434	1,122	15,205							
1915	22,901	35,662	196,503	381	21,222							
1916	37,280	51,663	102,451	197	16,053							
1918	745	602	22									
1920	5,339	7,304	10,029	318	11,241							
Seymour Canal:												
1906	3,000	10,000	60,000									
1912	2,385	20,383	274,459	236	4,199							
1913	968	10,540	103,293	452	1,140							
1914	1,685	13,040	110,359	11	274							
1916	3,404	36,835	407,190		2,302							
1917	252	18,801	229,976	19	949							
1918	1,394	57,695	270,298		85							
1919	906	19,792	32,458	21	3,085							
1920	208	37,384	44,460	2								
1922	250	19,352	38,018		5							
1923	245	31,622	108,245		619							
1924	614	21,137	197,651		970							
1925	670	17,788	20,314	44	306							
1926	36	45,459	135,671		35							
1927	16	19,373	65,133		288							
Shelter Cove:												
1924	16,930	32,066	75,835	1,550	15,870							
1926	375	10,999	20,927	55	4,542							
Snettisham, Port:												
1904	1,060	1,010	525	13	4,465							
1905		643		1	10,250							
1907					8,000							
1908		92	1,061		23,475							
1909					20,000							
1910					20,480							
1912		2,050	5,408		6,948							
1913		758	1,885	9	3,301							
1914		869	6,496	1	4,769							
1915		2,529	5,985		10,327							

TABLE 10.—*Salmon caught and fishing appliances used in the Stephens Passage district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Snettisham, Port—Contd.												
1918		826	69,718									
1919		9,029	11,706									
1920		620	2,164		269							
1922		682	5,898	20	7,288							
1923		434	1,973		2,471							
1924	220	614	1,632		7,944							
1926	3	4,037	7,961		8,730							
1927		717	8,315		8,176							
Taku Inlet:												
1904	13,568	7	128	29,214	50,599							
1905	20,630			22,362	72,353							
1906				2,696	48,724							
1907	41,981	44,770	15,908	10,701	23,937							
1908	32,352	8,286	1,842	10,757	38,862							
1909	36,889			7,384	69,000							
1910	46,397	16,425	500	21,597	58,304							
1911	40,824	38,865	24,661	45,017	34,885							
1912	38,440	45,255	9,059	8,088	19,892							
1913	17,647	8,891	8,635	9,985	14,014							
1914	46,731	32,211	11,043	16,996	20,378							
1915	37,108	17,652	34,355	12,099	30,300							
1916	58,182	58,318	13,902	13,048	16,431							
1917	32,251	19,357	39,272	8,239	32,721							
1918	25,239	6,561		7,781	36,600							
1919	33,350	66,157	50,117	9,713	35,060							
1920	34,076	43,088	24,162	21,977	30,134							
1921	57,047	13,000	40,000	10,049	24,044							
1922	34,882	23,192	8,373	6,474	26,920							
1923	24,845	9,224	12,030	12,900	8,791							
1924	24,825	16,565	19,988	17,088	22,314							
1925	40,066	20,212	13,832	16,232	19,685							
1926	26,836	18,462	20,241	7,801	39,028							
1927	41,160	11,530	37,032	8,177	11,103							
Tee Harbor:												
1904	636	8,441	6,549		3,198							
1908	4,471	1,825	6,187	6	4,471							
1912	1,426	8,174	4,934		2,409							
1914	120	3,550	11									
1915	818	4,941	8,522		4,504							
1916	348	2,034	2,068		1,683							
1917	283	419	648		281							
1918	5	1,076	1,040		329							
1925	69	17,090	1,335		753							
1926	3	25,927	13,737		145							
Windfall Harbor:												
1912		30	21,387									
1914	918											
1919	2	476	3									
1920	1	2,955	8,481									
1922		12,904	13,514									
1923		936	4,404		3							
1924		4,181	14,285									
Windham Bay:												
1907			65,397									
1912		581	59,515									
1913		530	38,548									
1916	307	5,363	481,986		56							
1917		494	18,391		7							
1918	138	54,663	371,715	1	149							
1919	6	225	1,248		15							
1920	13	10,410	59,089	2	47							
1922	2,045	20,774	137,008	20	1,641							
1923	580	2,950	36,935	12	524							
1924	3,152	30,486	565,974	21	4,426							
1925	919	14,723	42,667	19	1,238							
1926	1,981	30,527	416,981	2	3,935							
1927	709	3,737	38,840	16	371							
Young Bay:												
1912	646											
1918		14,321	13,951									
1923		451	902									
1924	519	2,112	5,369		2							
1926	7	22,104	2,470		27							
1927	1	880	46									
Unallocated:												
1904	7,118	9,254	132,345	2,454	18,704							
1905	7,430	39,487	38,686	1,907	27,070							
1906	37,449	29,374	144,447	17,470	39,242							
1907			22,500	8,000	4,800							
1908	9,271	36,490	248,537	7,445	39,684							

Table 10.—*Salmon caught and fishing appliances used in the Stephens Passage district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated—Continued.												
1909	16,560	6,562	120,145	9,033	41,389							
1910	31,000	61,200	186,500	457	47,000							
1911			8,250									
1912	292	39,244	16,556		10							
1913	1,695		19,320	1,131	1,574							
1914	4,067	1,138			626							
1916	500	7,472	227,965		6,071							
1917	29,634	146,785	1,077,372	4,603	81,516							
1918	5,362	185,235	468,988	6,078	4,288							
1919	21,305	141,710	97,922	4,687	16,126							
1920	13,149	78,489	290,015	2,129	9,018							
1921	29,829	44,647	128,062	20,000	17,607							
1922	46,505	61,231	135,900	1,305	10,364							
1923	32,318	71,642	233,960	16,299	39,070							
1924	10,478	16,104	30,210	2,347	4,404							
1925	10,489	105,333	94,178	2,951	8,732							
1926	1,790	59,017	282,117	821	12,294							
1927	4,225	31,191	74,702	381	6,331							
Total:												
1904	24,290	63,340	182,058	31,681	85,673	1		2		43		3
1905	33,488	68,690	71,936	24,270	140,226	5		4		56		7
1906	40,449	39,374	204,447	20,166	87,966	3		3		21		6
1907	41,981	44,770	215,820	18,701	36,737	2	150	2	325	5	1,000	
1908	46,094	46,693	263,707	18,208	106,492	1	150	1	175	10	1,750	5
1909	53,449	6,562	120,145	16,417	130,389							5
1910	78,663	77,625	187,000	20,054	125,784	2	150	2	325			4
1911	40,824	38,865	32,911	45,017	34,885	4	410	2	250	102	20,000	9
1912	74,328	209,348	633,903	9,608	76,443	7	1,000	8	1,500	31	2,700	6
1913	43,896	48,924	358,951	12,331	47,329	3	600	7	1,080	30	2,400	6
1914	73,540	121,390	288,405	18,130	41,252			7	1,165	52	9,360	4
1915	61,337	84,833	490,242	12,480	71,202			4	825			4
1916	101,751	249,633	304,607	13,265	44,986			14	2,435	88	9,800	8
1917	63,451	319,065	2,497,167	13,685	117,742			21	3,100	115	21,000	11
1918	35,621	652,869	2,074,337	14,523	43,858	15	1,520	42	7,605	92	18,200	13
1919	57,374	371,215	259,228	14,711	57,188	26	3,570	45	9,090	90	18,000	20
1920	53,401	295,328	600,006	24,503	51,665	21	3,325	34	5,966	90	18,000	23
1921	87,240	63,589	205,110	30,098	41,987	1	50	10	1,925	91	18,100	5
1922	85,658	232,499	697,325	7,850	47,591	9	1,250	28	4,570	59	8,550	9
1923	66,323	166,045	802,092	30,038	57,884			17	3,150	17	2,550	10
1924	59,922	309,581	1,989,561	21,389	62,389			39	6,825	21	3,150	17
1925	53,804	328,490	359,399	19,308	33,799			18	3,020	23	4,600	17
1926	34,113	467,077	1,889,245	8,683	76,063			36	6,525	49	9,340	10
1927	47,620	103,294	284,211	8,824	27,256			42	7,200	36	6,680	16

Note.—No catch was reported in the years not shown in any division of this table.

Table 11.—*Catch of coho and king salmon, by lines, in the Stephens Passage district, 1904 to 1924*

[Included in table 10]

Year	Coho	King	Year	Coho	King
1904		2,454	1913		125
1905		1,907	1916	300	
1906	3,000	17,470	1918	400	6,600
1907		8,000	1919	570	4,475
1908		2,465	1920		2,094
1909		7,600	1922		1,012
1910		9,163	1923		880
1911		10,930	1924		368
1912		2,371			

The most important salmon river in the district is the Taku, a large glacial stream and the outlet of several lakes in the Yukon Territory of Canada. Much of its importance is due to the presence of good runs of king and red salmon, which runs are also important factors in the Icy Strait fisheries. The river enters the head of Taku Inlet, a long narrow indentation of the mainland just north of the fifty-eighth parallel of north latitude, and one of the principal arms of Stephens Passage. The

river carries a large quantity of silt which discolors the water of the inlet for several miles, thus making possible the only important gill-net fishery in the district.

Presumably fishing began at the Taku about 1885 soon after the opening of canneries on Chilkat Inlet and for many years this locality made substantial contributions to the packs of the canneries at the head of Lynn Canal, yet in all those years no segregation of catches was made to show the number of salmon taken from Taku Inlet. Moser (1899, p. 126) says, in reporting on the pack of king salmon by the Chilkat canneries, "all that are packed at Pyramid Harbor are taken in the Taku, except a few stragglers that appear around the Chilkat very early in the season, which can hardly be called a run."

Taku River produces all species of salmon. The catches have been surprisingly uniform by species and from year to year. The largest catch of reds was 72,353 in 1905; of kings, 45,017 in 1911; pinks, 50,117 in 1919; chums, 66,157 in 1919; and cohos, 58,182 in 1916. Such even production, not exceeding 73,000 of any species in 24 years, has no parallel in any other locality. This consistently steady production is illustrated clearly in figure 26. After 1923 the catch of all species was affected by regulations, which in 1924 stopped fishing from August 11 to 31 and those in subsequent years which prohibited fishing from August 6 to September 5 and from October 15 to the end of the year, except gill netting from September 5 to October 15. Fishing was prohibited within 1 mile of the river after June 1924. Although it is improbable that the catch of kings was reduced materially by these regulations, as the run comes early, it is likely that the catch of all other species was considerably affected by these restrictions. There would be no purpose in such regulations if the catch were not reduced.

In assembling the data for Taku Inlet, it was necessary to divide the catches reported from Taku Inlet and Icy Strait in 1910, from Taku Inlet and Port Snettisham in 1919, from Taku and Chilkoot Rivers in 1922, and the unallocated catches of southeastern Alaska in 1906 and 1911. All salmon reported from Taku River from 1913 to 1919 were also included as Taku Inlet fish.

The trend of the catch of cohos maintains an even level almost from the development of the fishery to the end of the period herein treated, and there appears to be no marked change in conditions as a result of the restrictions that were applied in 1924 and in subsequent years. The fishing season, as limited in 1924, apparently caused a slight falling off in catch in that year but the larger catches in 1925 and 1927 again gave the curve a perceptible slope upward.

The catch of chums fluctuated more than that of any other species, and shows a rising trend up to 1918; thereafter it declined in a few years to the lowest point it had reached since 1908.

The pink-salmon fishery of Taku Inlet is relatively unimportant. Apparently little effort was made to take this species before 1911. Even in 1918, when most all other localities were highly productive, no pinks were reported from the inlet. The trend of this fishery reached its highest point in 1919, only to move downward with but one interruption to the low level of 1924. Although the better catches in 1926 and 1927 caused the trend to move upward, there is no indication that the catch will exceed greatly the best catches of the past, which occurred always in odd years.

The trend of the king-salmon catch has maintained a virtually constant level for more than 12 years. Except for the surprisingly large catch of 1911, the pro-

duction has been remarkably uniform. The last two years, 1926 and 1927, were among the poorest seasons this fishery has ever known, but the data disclose no

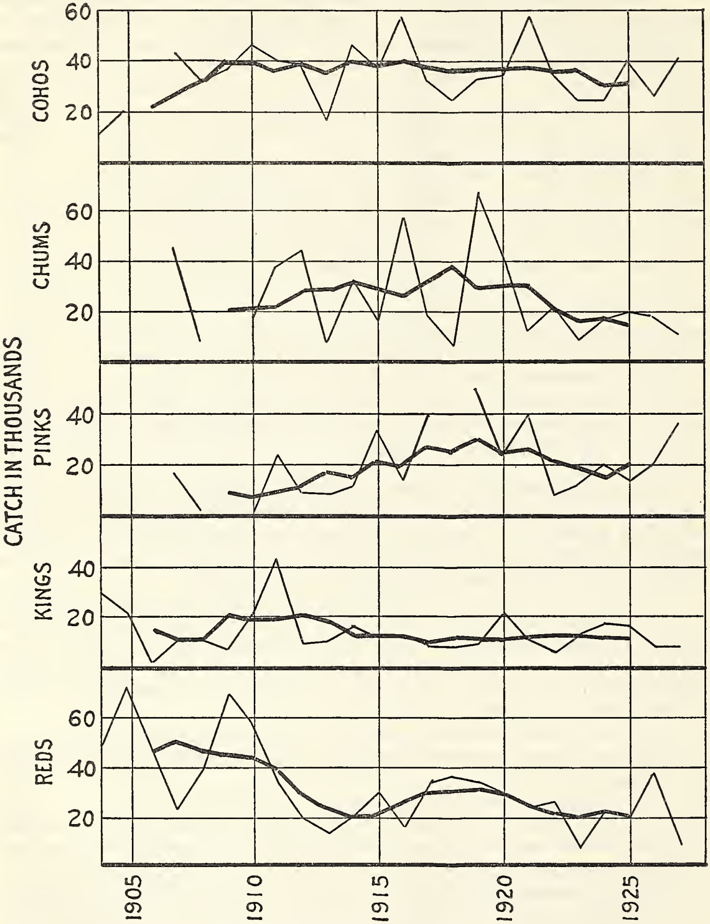

FIGURE 26.—Catch of salmon in Taku Inlet.

positive evidence of a failing supply. The run of kings, as those of all other species, is intercepted at many places before it reaches the inlet so that the real condition of the fishery cannot be determined alone by the catches in the inlet.

This fact is particularly noticeable in the red-salmon fishery, which shows a marked decline since 1910, and the trend of the catch is reaching lower levels as the seasons pass. How much of the Taku run is taken in Icy Strait and the lower part of Lynn Canal is not known, but the decline of this fishery is without much doubt correlated with the increase of fishing in those districts.

The mainland shore of Stephens Passage from Taku Inlet to Cape Fanshaw is indented by five bays of fair size, yet no important fishery has been developed within any one of them. Port Snettisham is the outlet of two large streams—Speel River and Whiting River—both of which support small runs of salmon. In 1900 a cannery was built on the southern shore at a location 2 miles east of Point Styleman and made small packs in 1900 and 1901, obtaining most of its king salmon from Taku Inlet, reds from Port Snettisham, and other species from Limestone Inlet and nearby streams. Considering the size and the number of streams which flow into this bay, it is one of the poorest salmon localities in southeastern Alaska. Since 1910 the annual catch of reds has not exceeded a few thousand, although in earlier years the annual catch was more than 20,000. The catch of all other species has been decidedly insignificant, except in 1918 when 69,718 pinks were reported from these waters. Salmon taken from Speel River in 1913, from Sweetheart Bay in 1918, and part from "Taku Inlet and Port Snettisham" in 1919 were included within the catch from Port Snettisham.

Windham Bay data indicate that an important pink-salmon run originates in that locality, and that chums are also present in fair numbers. The other species are also taken, but in limited numbers. These catches, however, were made chiefly by traps located at the entrance, or just outside the bay, and were probably not entirely of Windham Bay fish. Little fishing has actually been done in the bay. For reasons which have been explained above a part of the catch reported from Frederick Sound, Stephens Passage, and Sumner Strait in 1923 was credited to this locality as was also a part of the unallocated catch of southeastern Alaska in 1922 and 1924.

Hobart Bay has produced a considerable number of pinks and chums since 1912, the larger part of which came from traps located in the vicinity of Point Hobart and on the north side of the entrance to the bay and not actually from the bay. They were, however, reported as Hobart Bay fish to distinguish them from catches made elsewhere in Stephens Passage.

The records show that Port Houghton leads all the localities of this district in the production of pink salmon and holds third place in the yield of chums. This does not mean, however, that the entire catch reported as taken at Port Houghton came from local runs as a large part of it was taken from the general runs of Stephens Passage by traps at the entrance of the bay. The tagging experiments of 1924 at Point Kingsmill on Chatham Strait and at Cape Bendel on Frederick Sound disclosed that the main runs of salmon entering Stephens Passage from Frederick Sound strike the mainland shore between Port Houghton and Windham Bay. Tagged salmon were recaptured by traps along this shore, but there was no evidence that the streams of Port Houghton were providing a large proportion of the runs. On the contrary, it is probable that the runs were dispersed from this shore to all the bays of the eastern shore of the passage, if indeed, a considerable part did not cross the passage again to enter the streams of Admiralty Island. The catch seems to have been only slightly affected by the general regulations applicable in this district, but the orders of 1926 and 1927, closing Sanborn Canal, a small narrow bay on the south side of Port Houghton, may have reduced the catch slightly.

On the Admiralty shore of Stephens Passage are two important localities which have produced good runs of pink and chum salmon. These are Gambier Bay and Seymour Canal of which Pleasant Bay, Mole Harbor, and Windfall Harbor are tributaries. The catches from Gambier Bay probably include salmon caught off the entrance of the bay and therefore may not be exclusively Gambier Bay fish, but the Seymour Canal catches are undoubtedly properly allocated as most of the fishing in those waters was well within the canal. The possibility of error lies only in the division of comparatively inconsequential catches reported from Pleasant Bay and Security Bay in 1918 and from Kake and Seymour Canal in 1916. Due to the purity of these runs, it is possible to make a more detailed analysis of the Seymour Canal catches than can be made in respect of the runs in any other Stephens Passage locality, excepting possibly Taku Inlet. The combined catches of chums and pinks in Seymour Canal, Windfall Harbor, Mole Harbor, and Pleasant Bay, with small catches reported from Oliver Inlet in 1912 and 1913 and from Flaw Point in 1925, are shown graphically in figure 27. Other species are not considered because the catches were too insignificant.

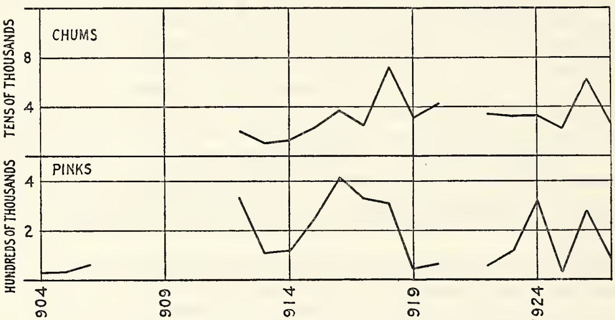

FIGURE 27.—Catch of chum and pink salmon in Seymour Canal, 1904 to 1927.

These graphs indicate that very little fishing was done in Seymour Canal before 1912, due perhaps to the absence of much competition for fish and the ability of the few packing plants then in the district to secure a supply of salmon nearer the canneries. With the establishment of more canneries on Stephens Passage, and an increase in the demand for salmon, Seymour Canal became a profitable field of operations and a consistent producer of pinks and chums until the economic break in 1921 and 1922. As the depression subsided, fishing was resumed, but the rather even production of pink salmon in the earlier years gave way to wide fluctuations which show good yields only in the even years, a condition very generally observed throughout southeastern Alaska. The catches in these years reached approximately the level of earlier good years notwithstanding the restrictions that were imposed in 1924 and subsequent years. The catch of chums since 1921 has held approximately the same level as it did before that time. There appears to be little evidence of depletion in the catches of pinks and chums in Seymour Canal.

Gambier Bay has made important contributions to the catch of chum and pink salmon in the Stephens Passage district, but the catch declined materially after the

permanent closing of the bay west of the one hundred and thirty-fourth meridian in 1925. The largest catch of both chums and pinks was made in 1918. The next 4 years, during which the fishing was less intense, were marked by considerably smaller catches. With the resumption of large-scale fishing in 1923, the catch of pinks again improved, but the catch of chums was even lower than in the preceding years of slackened effort. Available data do not indicate that this was due entirely to a scarcity of chums as there are reasons for thinking that that species was probably not fished intensively in 1923. The catch of both pinks and chums in 1924 closely approached the peaks of 1918, but from 1925 to 1927 the decline was apparently more serious than ever before and almost reached the vanishing point in the last year. It is not likely that this was caused wholly by the closing of the western part of the bay; but it may have been due to a change in the character of the fishing, or to an improper allocation of catches, rather than to depletion of the runs.

In the northern part of the Stephens Passage district are several localities of minor importance which have annually produced some salmon, mostly pinks and chums. The most important of these are Saginaw Channel and Shelter Cove where traps intercepted the runs to Lynn Canal and the passage. Neither of these localities has a fishery distinctively its own as there are no streams of consequence tributary to either. Runs to other waters move through these passages and come within reach of traps along the western shore of Shelter Island.

Two localities, False Point Pybus and Fanshaw Bay, in the southern part of the district, are given separate consideration in the table since good catches have been reported from both places in recent years. The data, however, are insufficient for more than passing notice at this time, but they may be useful in subsequent reviews of these fisheries.

WEST COAST OF CHICHAGOF AND BARANOF ISLANDS DISTRICT

This district covers the waters of the west coast of Chichagof and Baranof Islands from Point Urey southward to Cape Ommaney, with all the islands lying between these extremities. (See fig. 28.) The western shores of both islands are very rugged, particularly that of Baranof, the southwestern shore of which is indented by numerous narrow inlets extending several miles inland almost to the base of the mountain range which traverses the island from end to end. The northwestern section of Chichagof Island is also extremely mountainous even near the coast making a rough irregular shore without deep indentations or large streams. Under such physical conditions it is not surprising that the district embraces no large salmon stream, yet the streams, as small as they are, were among the earliest to be exploited in southeastern Alaska.

Salmon canning began in Alaska in 1878 with the opening of two canneries one of which was located at Old Sitka near the entrance to Katlian Bay about 6 miles north of the present town of Sitka. This plant was operated two seasons, obtaining its supply of fish mainly from Redoubt Lake. The pack in 1878 was 2,757 cases; in 1879 it was 5,855 cases. Thereafter the cannery was idle until it was dismantled in 1882 and the machinery transferred to a new cannery in another district in central Alaska. In 1889, a cannery was opened on Redoubt Bay, about 10 miles south of Sitka, and operated 2 years, making a pack of 4,454 cases in that year and 10,123 cases in 1890. It was moved to Redfish Bay, near the south end of Baranof Island,

in 1891, and operated each year to 1898. Two years later it was dismantled, having been sold to the Alaska Packers Association, and was moved to the Bristol Bay

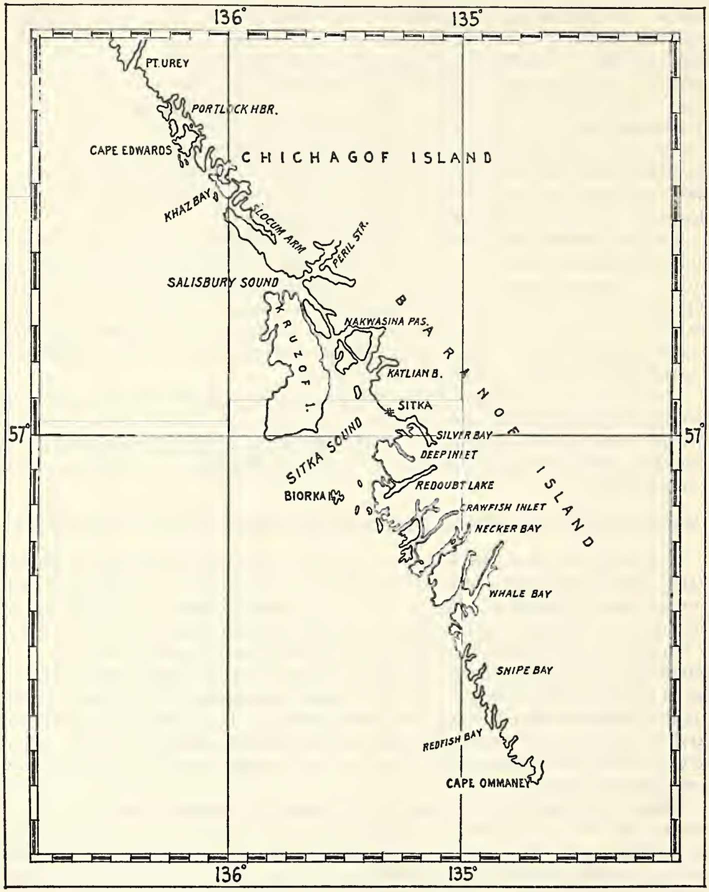

FIGURE 28.—Map of the west coast of Chichagof and Baranof Islands district.

district in western Alaska. The pack in cases during the 8 years it was operated at Redfish Bay is given in table 12.

TABLE 12.—*Pack of salmon at Redfish Bay, 1891–98*

Year	Pack	Year	Pack	Year	Pack	Year	Pack
	Cases		*Cases*		*Cases*		*Cases*
1891	7,949	1893	9,889	1895	14,805	1897	14,070
1892	10,259	1894	11,189	1896	15,358	1898	12,681

No record of the number of salmon of each species which composed these packs is now available, nor is there any record of the localities that were fished in these years. It is probable that all red salmon streams of the entire west coast of both islands were fished and that some salmon were also obtained from streams tributary to Chatham Strait. In the early history of salmon canning in this district, only red salmon streams were fished and the catch consisted almost wholly of red salmon, the few cohos that were taken being counted as reds. In later years, 2 canneries were built at Sitka and 1 at Ford Arm.

TABLE 13.—*Salmon caught and fishing apparatus used in the west coast of Chichagof and Baranof Islands district, 1904 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Chichagof Island:												
Black Bay:												
1911	617	1,276	11,058		9							
1912	1,423	6,634	25,925		380							
1913	1,283	14,150	10,160		328							
1915	433		19,702									
1916	190	21	2,047		13							
1917	3,057	33,779	190,452		149							
1918	4,329	40,550	146,894	4	6,027							
1919		809	429		481							
1920	3,594	42,719	15,230		1,688							
1922	756	4,137	4,200		4							
1923	848	3,502	11,146		374							
1924	2	1,884	4,435		53							
1925	178	29,360	12,031		2,686							
1926	879	23,986	83,744		3,702							
1927	726	11,515	12,230		879							
Dry Pass:												
1922			659									
1923	1,552		10,421									
1924	174	2,142	3,391		35							
1927	25	6,808	2,850		5							
Edwards, Cape:												
1904					59,000							
1905	1,993		13,557		23,791							
1906					5,585							
1909	1,681		308		23,860							
1910	4,172	10,210	75,710		9,249							
1911	7,957	1	301		21							
1912	242	2,411	4,709		1,033							
1913	2,119	63	590		140							
1919	1,051	2,286	1,051		2,058							
1920				17	171							
1922	58	20	155		461							
1923	9	1,208	5,009		1,441							
1924		23	14		340							
1925	27	2,093	802		3,944							
1927	6	863	317		7							
Falcon Arm:												
1922		11	1,442									
1923	56	103	6,213		255							
1925	8	1,734	6,175		133							
Ford Arm:												
1911	3,121	1,793	8,400		4,264							
1912	1,837	972	9,034		837							
1913	2,395	2,484	1,907		617							
1914	524	32	260		363							
1915			883		996							
1916	1,529	2,610	1,686		2,945							
1917	1,863	11,204	25,689		1,837							
1918	2,291	3,423	6,453	6	4,876							
1920	171	1,585	717		162							
1922	645	291	1,494		80							

TABLE 13.—*Salmon caught and fishing apparatus used in the west coast of Chichagof and Baranof Islands district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Chichagof Island—Contd.												
Ford Arm—Continued.												
1923		120	3,543		83							
1924		500	239		1,180							
1925	7	6,028	9,555		300							
1926		86	2,222									
1927	139	2,334	1,436		78							
Goloi Island:												
1927	2,822	4,292	21,610	127	582							
Klag Bay:												
1911	1,828	6,028	13,986		15,269							
1912	2,250	2,344	13,264		20,061							
1913	2,819	8,793	5,304		6,079							
1914	1,100	6,769	4,305		9,042							
1915	821	47	2,503		14,538							
1916	5,934	8,242	3,917		16,795							
1917	2,984	5,820	12,993		6,172							
1918	3,934	17,562	23,040	9	14,312							
1919		1,319	640		397							
1920	3,799	31,562	8,739	1	11,513							
1921					1,500							
1922	2,437	1,932	2,685		9,603							
1923	4,166	1,551	13,974		4,882							
1924	1,498	29,667	24,841		7,048							
1925	275	43,926	11,533	1	8,615							
1926	292	25,468	91,811		16,294							
1927	150	18,552	6,470		5,467							
Lake Anna:												
1915	820	47	2,502		14,537							
1917	2,531	23,829	187,059		3,387							
1918		106	171									
1926	5	25	123		71							
1927	63	2,031	1,262		622							
Pinta Bay:												
1911	630	4,095	1,251		10							
1912	904	4,175	2,809		18							
1913	1	123	2									
1918	2,322	19,439	2,854									
1922	2,183	6,938	13,970		6,602							
1923		195	3,396		177							
1924	82	1,193	1,874		245							
Porcupine Harbor:												
1905	2,812				889							
1906	452				464							
1907					1,016							
1908			1,046		4,493							
1909	1,070	52	3,265		4,291							
1910	4,190											
1911	1,798	21	892		5,379							
1912	571	500	33		3,552							
1913	446	1,324	713		4,163							
1914	923	599	1,985		5,170							
1915					579							
1918		1,081										
1922	480	82	1,969		267							
1923	487	642	1,371		480							
1924	35	159	2,083		2,379							
1925	3	297	1,297		294							
1926	155	197	2,772		2,462							
1927	170	273	248		2,006							
Portlock Harbor:												
1905	1,119		3,029									
1906	1,664		2,699		940							
1908	1,177											
1911	600	324	183									
1912	85	274	1,251		30							
1916	997				96							
1919	6	1,345	958		45							
1922		318	6,770		408							
1923	133	3	1,376		1							
1924	6	1,670	1,532		251							
1925	90	18,666	8,979		408							
1927	8	280	16		3							
Salisbury Sound:												
1915	163	33	917									
1922	758	651	1,161	2	106							
1925	1,201	18,260	22,039	1,170								
1926	1,482	15,184	69,840		1,159							
1927	6,052	11,411	47,806	108	962							
Salt Lake:												
1911	165	7,000	75,736									
1913	15	3,357	694		26							
1915			120		230							
1918	28	4,585	6,115									

TABLE 13.—*Salmon caught and fishing apparatus used in the west coast of Chichagof and Baranof Islands district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Chichagof Island—Contd.												
Salt Lake—Continued.												
1923	15	1,733	2,876		393							
1926		12	85		1							
1927	2		110		3							
Sister Lake:												
1912	287	6,251	24,943		532							
1913	23	415	318		136							
1914	1,614	10,281	4,720		9,116							
1918		956	819									
Slocum Arm:												
1911	16	3,637	48,123		268							
1912	99	4,776	81,483		18							
1913		1,437	6,580									
1914		4,333	30,502									
1915			19,702									
1916	793	14,542	37,503		10							
1917	538	17,764	296,625		139							
1918	1,300	32,608	138,333	8	2,811							
1920	2,520	14,112	35,818		1,651							
1922	3,484	12,233	41,067	8	478							
1923	673	4,477	115,125		1,015							
1924	282	11,965	50,762		932							
1925	2,013	43,406	82,596	30	16							
1926	550	22,280	211,933		6,542							
1927	275	11,583	7,183		2,277							
Waterfall Cove:												
1923	58	470	43,259		508							
1924	3	487	4,709									
1925	16	4,415	13,611		9							
1926	1	6,061	9,547		1,801							
Unallocated:												
1911	471	833	2,862		17							
1912	113	1,167	2,142		9							
1913	366	944	3,524		13							
1915			1,244		1,141							
1923	230	5	2,923		194							
1924	309	1	3,672									
1925	1,737	5,251	2,139	30	103							
1927	103	1,305	6,514		280							
Baranof Island:												
Banks, Port:												
1924	8	1,165	738		1,695							
1927	685	2,574	17		330							
Hayward Strait:												
1920	21	458	562	8	103							
1922	241	5,724	5,460									
Katlian Bay:												
1918	116	6,745	9,912	3								
1920	301	38,202	3,158	10	100							
1922	101	463	1,514									
1923	494	1,834	15,100		793							
1924	99	2,425	1,377									
1926		393	586		2							
1927	172	6,703	2,707		9							
Mud Bay:												
1922	131	6,871	6,528									
1923	260	1,258	10,620									
1927		562	737									
Nakwasina Passage:												
1918	927	36,182	127,960									
1919	4,920	14,260	17,624	26	7,561							
1920	1,521	36,227	2,728	52	6,225							
1922	1,426	7,856	6,723									
1923	4,841	627	16,742		226							
1924	1,004	24,253	34,920		89							
1925	6	8,847	4,231									
1926	3	9,708	23,163		166							
1927	51	6,337	5,111		7							
Necker Bay:												
1906					10,100							
1907		5	163		13,873							
1911					11,259							
1912		55	305		4,864							
1913					40,679							
1914					41,437							
1915					13,819							
1916	195			24	27,692							
1917	377	5	372		7,388							
1918					12,768							
1920	1	9,586	1,224		15,320							
1921					20,262							
1922				1	2,884							
1923	399	820	14,890		19,224							

TABLE 13.—*Salmon caught and fishing apparatus used in the west coast of Chichagof and Baranof Islands district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Baranof Island—Continued.												
Necker Bay—Continued.												
1924	1,204	1,357	647	----	10,253	----	----	----	----	----	----	----
1925	921	----	----	----	20,815	----	----	----	----	----	----	----
1926	3	7	576	----	15,598	----	----	----	----	----	----	----
1927	338	1	63	----	15,958	----	----	----	----	----	----	----
Old Sitka Harbor:												
1918	346	7,027	29,760	----	----	----	----	----	----	----	----	----
1919	1,462	6,228	3,271	15	824	----	----	----	----	----	----	----
1920	108	1,807	881	6	227	----	----	----	----	----	----	----
1922	----	5,292	12,940	----	----	----	----	----	----	----	----	----
1923	142	154	10,517	----	1	----	----	----	----	----	----	----
1924	658	4,569	19,311	----	4	----	----	----	----	----	----	----
1925	6	8,131	15,371	----	----	----	----	----	----	----	----	----
1926	----	141	1,181	----	----	----	----	----	----	----	----	----
1927	----	1,094	85	----	3	----	----	----	----	----	----	----
Redfish Bay:												
1904	----	----	----	----	30,000	----	----	----	----	----	----	----
1905	----	----	----	----	15,000	----	----	----	----	----	----	----
1906	----	----	----	----	15,000	----	----	----	----	----	----	----
1907	----	----	----	----	26,242	----	----	----	----	----	----	----
1908	----	----	----	----	26,000	----	----	----	----	----	----	----
1909	----	----	----	----	19,400	----	----	----	----	----	----	----
1910	----	----	----	----	22,939	----	----	----	----	----	----	----
1911	----	----	----	----	25,358	----	----	----	----	----	----	----
1912	2	15	----	----	26,169	----	----	----	----	----	----	----
1913	----	----	39	----	9,672	----	----	----	----	----	----	----
1914	306	4	288	----	21,050	----	----	----	----	----	----	----
1915	476	21	2,616	----	8,311	----	----	----	----	----	----	----
1916	759	244	2,828	----	19,680	----	----	----	----	----	----	----
1917	----	----	----	----	7,401	----	----	----	----	----	----	----
1918	2,117	1,100	844	----	8,355	----	----	----	----	----	----	----
1919	437	----	----	----	8,129	----	----	----	----	----	----	----
1920	5	11,619	1,765	76	25,756	----	----	----	----	----	----	----
1921	1,000	----	----	----	31,581	----	----	----	----	----	----	----
1922	773	25	21	----	17,080	----	----	----	----	----	----	----
1923	11	5	107	----	16,143	----	----	----	----	----	----	----
1924	320	1,478	280	----	35,217	----	----	----	----	----	----	----
1925	----	----	----	----	16,478	----	----	----	----	----	----	----
1926	----	----	----	----	3,842	----	----	----	----	----	----	----
1927	1	545	605	----	253	----	----	----	----	----	----	----
Redoubt Bay:												
1904	----	----	----	----	27,000	----	----	----	----	----	----	----
1911	26	4	790	----	11,375	----	----	----	----	----	----	----
1912	----	----	50	----	9,965	----	----	----	----	----	----	----
1913	----	----	----	----	13,390	----	----	----	----	----	----	----
1914	----	----	956	----	31,000	----	----	----	----	----	----	----
1915	----	----	----	----	28,628	----	----	----	----	----	----	----
1916	23	4	71	----	8,151	----	----	----	----	----	----	----
1917	----	446	66	5	1,532	----	----	----	----	----	----	----
1918	----	----	----	----	20,253	----	----	----	----	----	----	----
1919	2,624	12,631	15,820	67	12,780	----	----	----	----	----	----	----
1920	1,673	12,546	1,435	68	17,658	----	----	----	----	----	----	----
1921	----	----	----	----	6,000	----	----	----	----	----	----	----
1922	150	326	312	----	1,148	----	----	----	----	----	----	----
1923	16	277	1,673	8	12,141	----	----	----	----	----	----	----
1924	337	740	524	123	3,434	----	----	----	----	----	----	----
1925	----	----	----	700	2,358	----	----	----	----	----	----	----
Silver Bay:												
1923	123	2,326	8,429	----	67	----	----	----	----	----	----	----
1924	28	1,639	15,197	----	50	----	----	----	----	----	----	----
1925	95	1,614	5,059	400	----	----	----	----	----	----	----	----
1927	2	512	298	----	237	----	----	----	----	----	----	----
Sitka Sound:												
1918	2,400	1,000	6,500	----	70	----	----	----	----	----	----	----
1919	5,134	42,148	20,990	33	4,762	----	----	----	----	----	----	----
1920	4,024	31,237	6,501	11,723	6,672	----	----	----	----	----	----	----
1921	6,050	----	----	5,122	----	----	----	----	----	----	----	----
1922	----	----	----	5,000	----	----	----	----	----	----	----	----
1923	----	----	----	30,000	----	----	----	----	----	----	----	----
1924	660	1,347	2,145	4,247	----	----	----	----	----	----	----	----
1925	2,211	----	2,157	18,772	----	----	----	----	----	----	----	----
1926	3,077	749	43	8,593	----	----	----	----	----	----	----	----
1927	39,363	3,559	2,445	----	3	----	----	----	----	----	----	----
St. John Baptist Bay:												
1918	----	18,017	4,260	----	----	----	----	----	----	----	----	----
1925	4	1,170	3,808	----	4	----	----	----	----	----	----	----
1927	7	1,924	2,515	----	4	----	----	----	----	----	----	----
Whale Bay:												
1911	1,760	21	214	----	943	----	----	----	----	----	----	----
1912	941	97	40	----	2,096	----	----	----	----	----	----	----
1913	----	----	----	670	39	----	----	----	----	----	----	----
1915	452	112	6,230	----	8,098	----	----	----	----	----	----	----
1916	2,579	11	76	----	7,776	----	----	----	----	----	----	----

TABLE 13.—*Salmon caught and fishing apparatus used in the west coast of Chichagof and Baranof Island district, 1904 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Baranof Island—Continued.												
Whale Bay—Continued.												
1917	1,765	12,918	26,501		5,183							
1918	3,345	1,035	19,100	7	19,746							
1919	2,493	16,447	31,859	42	25,118							
1920	885	11,289	1,937	50	7,497							
1921	5,028	3,623	41,343		4,382							
1922	6,919	1,859	4,131	2	4,462							
1923	1,792	760	13,120	2	5,954							
1924	1,844	2,214	2,713		6,365							
1925	3,288			6	3,018							
1926	2,910	248	1,447	35	5,248							
1927	1,570	516	1,679		1,291							
Unallocated:												
1911	4,603	9,842	20,183		56							
1912	3,174	1,324	3,344		28							
1913	4,488	20,119	28,750	10,811	34							
1914	5,869	15,626	33,146	16,390	2,785							
1915	487											
1916	5,320	18,710	48,355	555	200							
1917	4,673	30,968	80,598	28,813								
1918	18,962	23,976	2,283	34,227								
1920					376							
1921	5,000											
1922	13,492	58		26,892	22,487							
1923	40,994			268,071								
1924	9,572	1,047	63	42,504	85							
1925	42,581	2,283	2,405	57,625	548							
1926	51,889	529	445	70,129	52							
1927	37,510	280	387	82,211	79							
Total:												
1904					116,000			6				
1905	5,924		16,586		39,680			5				
1906	2,116		2,699		32,089			5				
1907		5	163		41,131			5	775			
1908	1,177		1,046		30,493			3	420			
1909	2,751	52	3,573		47,551			3	415			
1910	8,362	10,210	75,710		32,188			5	800			
1911	23,592	34,875	183,979		74,228			13	1,925	10	700	
1912	11,928	30,995	169,332		69,592	7	900	14	2,305			
1913	13,955	53,209	58,581	11,481	75,316	8	1,200	4	700			2
1914	10,336	37,644	76,162	16,390	119,963	1	200	11	1,650	8	200	
1915	3,652	260	56,419		90,877			10	1,360			
1916	18,319	44,384	96,483	579	83,358			10	1,410			
1917	17,788	136,733	820,355	28,818	33,188			12	1,560			
1918	42,417	215,392	525,298	34,264	89,218			27	4,555			
1919	18,127	97,473	92,642	183	62,155			21	3,450			
1920	18,623	242,949	80,695	12,011	95,119	8	400	21	3,475			2
1921	17,078	3,623	41,343	5,122	63,725			2	300			
1922	34,034	55,077	113,201	31,905	66,070			26	4,390			1
1923	57,299	22,070	311,830	298,081	64,352			23	3,940			3
1924	18,125	91,925	175,467	46,874	69,655			22	3,630			
1925	54,667	195,481	203,788	78,734	59,729			24	3,895			
1926	61,246	105,074	499,518	78,757	56,940			22	3,650	5	500	1
1927	90,240	95,854	124,701	82,446	31,345			25	4,370			2

NOTE.—No catch was reported in the years not shown in any division of this table.

The total catch of salmon in this district from 1904 to 1927 is shown in table 13. Earlier catches, as taken from various published reports, are referred to in the discussion of data for the localities affected. This table lists 29 localities, of which 16 are on the Chichagof shore and 13 on the Baranof shore. The most important streams of Chichagof Island are found in Black Bay, Ford Arm, Klag Bay, Lake Anna, Pinta Bay, Porcupine Harbor, Portlock Harbor, and Slocum Arm. Considerable catches were also made at Cape Edwards and Salisbury Sound. Of these several localities, 6 have been fair producers of chum, pink, and red salmon. Considering the size of the streams, large catches of chums and pinks were made in a few years at Black Bay, Klag Bay, and Slocum Arm. Reds and cohos were also taken, but in much smaller quantities, while kings were seldom reported. The largest catch of kings in the Chichagof section was made by trollers at Salisbury Sound in 1925.

Except for phenomenal catches of pinks in 1917 and 1918, Black Bay, which is credited with part of the catch reported from Slocum Arm and Black Bay in 1915, shows no marked change in the production of salmon since the runs in that locality were first exploited. Catches were about as good in 1927 as they were when fishing began in 1911.

The fisheries at Cape Edward, if, indeed, any ever existed at that exposed point on the west coast of Herbert Graves Island, apparently have been almost exhausted. However, it seems improbable that the catches reported from this locality could actually have been made there. They may have come from Portlock Harbor and its tributary bays, but were designated as Cape Edward fish for the simple reason that little attention was given to exact allocation of catches when the fisheries of this region were first utilized. In the same way the cannery, which was built on Ford Arm in 1911, was long known as the Cape Edward cannery, although it was located several miles from the cape.

Klag Bay appears to have been first fished in 1911, coincident with the opening of the Ford Arm cannery, as happened at several other localities on this coast. The catches from this bay include all salmon reported from Fish Camp and half of those from Fish Camp and Lake Anna and from Fish Camp and Sister Lake in 1915. While the total number of salmon from Klag Bay in 1926 and 1927 is somewhat less than the catch in several preceding years, there is no definite indication that the runs are failing. These smaller catches probably were due to a reduced fishing effort, as the Ford Arm cannery was not opened after 1924.

Lake Anna, which is not a lake at all but is an arm of Khaz Bay, shows exceptionally large production of pinks and a fair yield of chums in 1917, while the catch in 1918 was almost nothing. No further catches were reported from this locality until 1926 and 1927, and in both years only a few fish were caught. Why 187,059 pinks were taken in Lake Anna in 1917 and in all other years the catch was less than 3,000 annually, is not explained by the available data, but is probably due to faulty allocation.

Pinta Bay was fished so intermittently, or the catches, if any, were not always correctly reported, as to leave few data for comparative study. If the records as shown in the table are complete, this bay has never provided a valuable run of salmon. The catches were extremely poor in all years, except 1918 and 1922, and even the returns in these better seasons, especially that of 6,600 reds in 1922, are open to question.

Porcupine Harbor has produced more red salmon than any other species, but the catches have not exceeded a few thousand fish in any year. It was one of the first places on the Chichagof coast to be fished, doubtless due to the presence of red salmon, but operations were evidently suspended just before and after 1918 for periods of two and three years respectively, indicating that the runs were seriously reduced by that time. No reds were taken after 1915 until 1922 and no cohos and pinks after 1914 until the same year. The data, covering 18 years fishing, indicates that no important fishery can be established in this locality.

In many respects, Portlock Harbor, apart from its tributary bays, is similar to Porcupine Harbor. Operations have been very irregular and catches small, although more chums and pinks were taken in 1925 than ever before. Data for Salisbury Sound cover 5 years. Exploitation of the fisheries of this locality since 1924 has resulted in the catch of several thousand salmon, mostly chums and pinks. In addition, the catch by a trap at Goloi Island in 1927 should also be included with fish from the

sound, although it is kept separate in the table for future use. To what extent these catches are made from runs to the streams of Peril Strait or the west coast of Baranof Island is not known, but it may be presumed safely that not all of the salmon caught in the sound come from local runs. The streams tributary to the sound are small and doubtless provide comparatively few salmon, as no large catches were made there before 1925.

The most important fisheries of the west coast of Chichagof Island are found in Slocum Arm, including the connecting bays at Ford Arm, Falcon Arm, and Waterfall Cove. Their development began apparently in 1911 with the opening of the Ford Arm cannery and continued through 1927, although no catches were reported in 1919 and 1921. Pinks and chums are the predominant species while reds and cohos are present in about the same proportions as in most all localities on the Chichagof shore. The catch of pinks apparently has fluctuated widely, the largest yield being recorded in 1917. Good catches were also made in 1918, 1923, and 1926, while the intervening years were far less productive, 1927 being next to the poorest year in the history of the fishery. The catch of chums has been more regular than that of pinks, but has dropped markedly since 1925, the year of largest production.

Three localities of minor importance in the Chichagof section, Dry Pass, Salt Lake and Sister Lake, were small producers of all species of salmon except kings.

The unallocated catch of salmon along the Chichagof shore came from Hearst Cove in 1911, 1912, and 1913; Deep Bay in 1927; Stag Bay to Ogden Passage in 1913; Sea Level in 1924; Imperial Passage in 1925; Leo Anchorage in 1915 and 1923; and from Ogden Passage and Small Arm in 1923. In most cases the catches were small and the localities were rarely fished more than one season.

The west coast of Baranof Island has never been a large producer of salmon, although it was one of the first districts to be developed in southeastern Alaska, due to the location of a cannery at Sitka and later at Redfish Bay. The streams are comparatively small, yet some of them have been steady contributors to the catch of salmon through many years. Among these are Redoubt, Necker, Redfish, and Whale Bays. Redfish Bay became better known than the others, probably for the reason that a cannery was erected on its shore in 1891 after the original site of this plant at Redoubt Bay was abandoned. This move brought the cannery nearer to the better fishing grounds on the west coast of Baranof and also made more accessible some important streams tributary to Chatham Strait.

No available records indicate the composition of the packs at Redoubt Bay in 1889 and 1890 or give any information as to the localities where the fish were obtained. Presumably they were mostly red salmon and were taken at the streams already mentioned. Similar information is also lacking in regard to the packs at the Redfish Bay cannery from 1891 to 1898. In 1899 Moser reported the catch at the Redfish Bay stream for several years as given in table 14.

TABLE 14.—*Catch of salmon at Redfish Bay from 1890 to 1897*

Year	Catch	Year	Catch	Year	Catch
1890	24,367	1893	26,434	1896	15,000
1891	[1] 53,310	1894	69,553	1897	20,000
1892	48,000	1895	40,969		

[1] Includes a few cohos.

In addition to these catches, which were supposedly red salmon except as noted, 303 cohos were taken here in 1893 and 1,152 in 1895. It was also reported that this cannery packed 103,541 reds, 10,825 cohos, and 88,849 pinks in 1896; 64,509 reds, 8,351 cohos, and 1,942,028 pinks in 1897; and 139,490 reds in 1898. The difference between these catches of red salmon and those given in table 14 for the same years represents the number of red salmon that came from localities other than Redfish Bay. A company operating at Petersburg took 34,000 red salmon from this bay in 1900. None of these figures appears in table 13, which gives only the catches from 1904 to 1927.

For many years the only catches reported from Redfish Bay were of red salmon. Since 1912 all other species have been taken but not in sufficient quantities to constitute important fisheries. With one exception, a catch of 11,619 chums in 1920, the number of salmon of each species, exclusive of reds, did not exceed 3,000 fish. Fluctuations in the catch of red salmon is shown graphically in figure 29.

Disregarding the rather large catches in the years immediately following the opening of the cannery at Redfish Bay, no marked fluctuations occurred in the catch of red salmon until after 1912. From 1913 to 1919, there were 5 years of extremely poor catches, and 2 years, 1914 and 1916, of fairly good yields. The catch in 1918 includes 149 reds reported from Redfish Cape. The next period, 1920 to 1924,

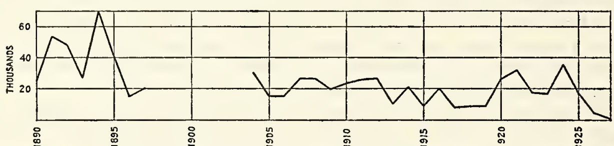

FIGURE 29.—Catch of red salmon at Redfish Bay, 1890 to 1927.

shows catches which compare favorably with the catches from 1904 to 1912 indicating that an appreciable run still survives.

The red-salmon season varies considerably at this bay, the range of the opening date being from June 1 to July 29, and the closing date from August 6 to September 26. In 1924 fishing was prohibited from August 20 to September 9; in the next 3 years the closed season extended from August 18 to September 14; and in 1926 the northern part of the bay was permanently closed. The seasonal closing in 1924 had little or no effect upon the catch as more red salmon were taken that year than in any year since 1895, indicating either an earlier or a larger run. In 1925 the catch was much smaller due, not necessarily to the longer closed season, but possibly to a poor run of salmon. The closing of the northern part of the bay in 1926 easily accounts for the small catches in that and the following year. Further commercial utilization of the red salmon of Redfish Bay seems doubtful under these restrictions as it is not likely that fishing will be profitable in the lower reaches of the bay until the run increases far beyond its present size.

Little is known of the Whale Bay fisheries before 1911, but that locality was probably fished as early as Redfish Bay, chiefly for red and coho salmon. The catch of these species has always been small, except in 1918 and 1919, when nearly three times as many reds were reported taken as ever before or since. No marked reduction is indicated by the available statistics, although the regulations of 1924 and subsequent years were intended to reduce the catch. The closing of Still Harbor

and Port Banks, small bays on the southern side of Whale Bay, could hardly have had much effect upon the catches in this locality. The first catch reported from Still Harbor was 190 reds in 1916; the second was 5,000 cohos in 1921; the third, 1,243 cohos, 468 chums, 56 pinks, and 82 reds in 1924; and the last, 549 cohos and 545 reds in 1925. The catches of cohos were probably made by trollers in offshore fishing who used this harbor as a base of operations and point of delivery to the packing companies.

The situation at Port Banks is somewhat different as all species except kings were taken there in 2 years, 1924 and 1927. No salmon were reported from this locality in 1925 and 1926, but after the closing of the bay in 1927 the catch in that year was still equal to that of 1924. As a measure of conservation, the prohibition of fishing for salmon in Still Harbor and Port Banks would seem to be of doubtful value, as neither locality can support a commercially valuable run of salmon.

Necker Bay is noted for its run of small red salmon. Moser reported in 1899 that "the average number of fish per year taken from this locality by the cannery during the past 9 years is 40,000; the largest number in any 1 year was 105,572. They are fully matured, and run from 28 to 30 to the case, or an average weight of about 2½ pounds per fish." This is the only known record of the productivity of Necker Bay before 1906. Omitting the years from 1908 to 1910 and that of 1919, this bay has been a regular producer of red salmon, and while the catch was fairly consistent, and the average catch per year was considerably lower than that given by Moser for earlier years, there is no evidence in this extended record of red-salmon catches that the run has appreciably changed during the past 20 years. Other species are taken irregularly in Necker Bay but the catches are inconsequential.

Redoubt Bay, into which Redoubt Lake empties, was one of the first fishery localities to be exploited in all Alaska. In the early days of Alaskan exploration and the founding of a settlement at Sitka, the Russians depended very largely upon the red salmon of Redoubt for a supply of fish. The stream was barricaded and fished unrestrictedly without the slightest regard for the preservation of the run of salmon. The inevitable result of this reckless fishing which continued and reached its height several years after Alaska was sold to the United States was the virtual destruction of the salmon runs. Even in 1889 and 1890 the supply of fish was insufficient for the profitable operation of a small cannery and as long ago as 1900 the production of salmon here had dropped almost to the vanishing point. After the approval of the act of Congress of 1906, making barricades in streams unlawful, and giving other protection to the salmon fisheries of Alaska, there was some slight improvement in the run at Redoubt, but with all the protection that was then given and has since been given to this stream, the run has not yet regained its former proportions. In 1926 all fishing in the bay within 1,000 yards of the mouth of the stream was prohibited and thus put an end to fishing in that locality as no salmon have been reported from Redoubt since 1925. In view of its history it seems possible that, under careful control and wise measures of conservation, this stream may again become an important source of red salmon.

Small catches, mostly of chums and pinks, were made infrequently in Hayward Strait, Mud Bay, and St. John Baptist Bay. Katlian Bay (which includes catches from "Katalina Bay" in 1920 and 1924 and from "Katlianski" in 1924), Nakwasina Passage, Old Sitka Harbor, Sitka Sound (which includes catches from De Groff Bay in 1926), Cape Burunof, Olga Strait, Sukoi Inlet, and Whitestone Narrows in 1927,

show considerably larger production of these species. Several thousand king salmon were also taken by trollers in Sitka Sound. The unallocated catches on the west coast of Baranof Island includes small catches from Salisbury Sound in 1916; from Pacific Ocean in 1922, 1923, and 1924; from Puffin Bay in 1917 and 1924; from Still Harbor in 1916, 1921, 1924, and 1925; from "Salisbury Sound to Whale Bay" in 1914; from Baranof Island in 1927; from Hot Springs Bay in 1911, 1912, and 1924; from Crab Bay in 1918 and 1925; from "Cape Edgecomb to Sea Lion Cove" in 1918 and 1927; from Crawfish Inlet in 1920, 1922, and 1924; and from "Sitka to Salisbury Sound" in 1911, 1912, 1913, and 1917. All king and coho salmon which were taken by lines in off-shore fishing from Salisbury Sound to Cape Ommaney are included in the unallocated and total catch sections of table 13. This section of the coast is an important feeding ground of king and coho salmon and constitutes one of the most profitable fields of operations of the trollers whose fishing may be carried on without limitation of season or restriction of gear. The total catch of salmon by lines in the west coast of Chichagof and Baranof Islands district is shown in table 15.

TABLE 15.—*Catch of coho and king salmon in the West Coast of Chichagof and Baranof Islands district, by lines, 1911 to 1927*

[Included in table 13]

Year	Coho	King	Year	Coho	King
1911	1,472		1920		11,714
1912	1,394		1921	11,050	5,122
1913		10,811	1922	9,146	31,887
1914		16,390	1923	40,994	298,071
1915	487		1924	8,543	46,874
1916	4,531	555	1925	48,792	78,127
1917	1,558	28,813	1926	57,607	78,757
1918	17,077	34,227	1927	76,869	113,239

NOTE.—No catch was reported in 1919.

PERIL STRAIT

The Peril Strait district embraces all the waters of Chichagof and Baranof Islands between Kakul Narrows at the western entrance of the strait and a line from Point Craven to Point Thatcher at the eastern entrance. (See fig. 30.)

Within these limits are 11 localities from which salmon have been consistently taken, only 1 of which, Rodman Bay, shows any production before 1911. It is likely, however, that some of the other bays were fished much earlier than the recorded data indicate as in the earlier years practically the entire catch in Peril Strait was unallocated. Exploitation of these fisheries doubtless began when canneries were established at Freshwater and Sitkoh Bays, but no records are now available showing the catches in this district before 1904. The known development, however, as disclosed in the reported catches in Peril Strait, dates from 1904 with a catch of 60,000 pinks in Rodman Bay and an unallocated catch of 7,000 reds, probably from Hanus Bay into which flows the outlet of Lake Eva, the only recognized red-salmon stream in the entire district. It is fair to assume that all of the unallocated catches of red salmon in Peril Strait came from this locality. Unfortunately, a very large part of the whole catch of salmon in the Peril Strait district, from 1904 to 1927, was reported without allocation to any of the several bays in that region. As a result of this faulty method of recording catches, Rodman Bay apparently produced no fish after 1904 until 1918, a most unlikely condition when viewed in the light of the

fact that more salmon were taken in that locality in 1904 than in any other section of the strait. Presumably, Rodman Bay was fished regularly but the catches were shown only as coming from the strait. The catch of 60,000 pink salmon in 1904 was never closely approached in any subsequent year. After a lapse of 13 years the catch in 1918 was 2,300 and for the next 4 years it did not exceed 8,000. This period of low production was followed by one of larger catches, culminating in a total of 29,890 in 1925 only to fall again in the last two years. Chum salmon were also taken in Rodman Bay. In the 9 years of fishing, the catches exceed 10,000 in 2 years only, 1925 and 1926, when 90,244 and 20,185, respectively, were caught.

In the 8 years it has been fished, Bradshaw Cove, near the western entrance of the strait, shows a fairly constant production of pinks and chums. Relatively good catches of cohos and reds have also been reported. The record, taken at its face

FIGURE 30.—Map of the Peril Strait district.

value, indicates that the best runs of salmon in the Peril Strait district are found at this cove, the catches having been consistently larger here than elsewhere in the district. The cove, however, has no salmon runs of importance, and to that extent statistical data showing catches of salmon in that locality are misleading. These catches were made by a trap at the entrance of the cove so placed that it intercepted the passing runs of salmon. In 1921, the trap was not operated, consequently no salmon were reported as caught here, a fact which emphasizes the conclusion that the cove has no runs distinctively its own. The salmon taken at this point come undoubtedly mainly from runs to other localities. More pinks, kings, and reds were reported taken here than in any other section of the district in the same period. Fish Bay alone produced more cohos and Rodman Bay more chums than Bradshaw Cove.

Other localities have little importance, although fair catches of chums and pinks were made in some years at Fish Bay and Hooniah Sound. Approximately half of the salmon taken in this district were unallocated. These totals were increased slightly by the inclusion of small catches from Broad Island, Frick Cove, and Louise Cove in 1925; from "Hydens Bay" (an unknown locality) in 1924; from Bear Bay in 1919; and from Fish Cove in 1922. It was also necessary to include parts of certain catches that had been grouped by the canning companies under a general locality name such as "Icy, Chatham, and Peril Straits and Bays." The method used in the division of such catches was explained in the review of the data for Icy Strait and other districts similarly affected and need not be repeated here. It is also probable that king and coho salmon were taken in Peril Strait by lines, but all such catches were hopelessly mixed with catches in other districts so that a division of the fish is now an impracticable undertaking. These catches were included, therefore, in the Chatham Strait data.

TABLE 16.—*Salmon caught and fishing appliances used in the Peril Strait district, 1904 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Bradshaw Cove:												
1918	2,667	14,245	36,845		598							
1919	4,352	14,057	22,871		1,102							
1920	3,874	12,958	82,116	4	3,670							
1922	1,538	3,916	19,299		538							
1923	728	4,295	39,042	6	711							
1925	264	19,126	34,625		1,054							
1926	1,098	10,458	80,839		1,205							
1927	3,301	4,696	25,844	68	822							
Deep Bay:												
1918			3,500									
1923	475	3,454	31,567		4							
1924	4	880	6,618		1							
1925	3	3,059	6,614									
1926		287	4,451									
Fish Bay:												
1911		2,810	9,436									
1917	2,000	1,336	11,087									
1918	11,412	5,164	9,195									
1919	604	11,131	6,216	1	567							
1921	3,000											
1922	3,220											
1923	3,122		3,551									
1924	35	5,217	4,923		161							
1925	93	22,706	33,095		1,065							
1926	27	7,003	8,952		574							
1927	13	1,139	2,168		10							
Hanus Bay:												
1915					168							
1916		575	21,583	12	1,479							
1917	1	1,090	7,090									
1922					450							
1924					3,551							
Hanus Point:												
1926	400	2,000	38,038		2,500							
Hooniah Sound:												
1913		159	1,373									
1916	26	2,036	38,943									
1920	392	762										
1923	793	4,636	38,275		63							
1924	167	7,236	16,467		6							
1925	109	49,849	55,379		31							
1926	4	12,715	7,205		1							
1927	33	3,320	10,394		163							
Patterson Bay:												
1918	51	352										
1926	367	2,520	108									
Poison Cove:												
1918	1,243	12,115	24,193		287							
1923		3	518		32							
1925		1,767	7									
1926	480	6,741	53,460		2							
Rodman Bay:												
1904			60,000									
1918		8,280	2,300									
1919		6,999	7,229									

TABLE 16.—*Salmon caught and fishing appliances used in the Peril Strait district, 1904 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Rodman Bay—Continued.												
1920		143	659									
1922			8,000									
1923		750	10,093									
1924	8	5,694	12,112		101							
1925	72	90,244	29,890		110							
1926		20,185	15,667		5							
1927	24	6,458	12,646		53							
Saook Bay:												
1918		6,545										
1923	74	221	13,960									
1924		357	8,482									
1925	2	1,582	16,260		5							
1926		1,722	5,258		16							
1927		677	279									
Ushk Bay:												
1923		82	978									
1924		525	2,482									
1925	17	12,537	5,064		1							
1926		818	3,419		1							
1927	1	79	390									
Unallocated:												
1904					7,000							
1905	854	7,868	16,344		1,772							
1906	679	9,034	32,194		5,116							
1907	1,376	12,458	37,775	11	4,271							
1909	526	5,293	20,842	42	13,050							
1910	1,528	12,406	24,031	34	7,936							
1911	1,824	15,775	37,152	32	4,182							
1912	755	13,791	18,159	12	2,640							
1913	758	3,448	44,058	9	4,636							
1914	1,481	6,546	15,568	64	6,281							
1915	540	2,530	43,627	70	4,507							
1916	2,074	6,454	46,733	6	3,338							
1917	7,324	43,476	68,368	40	6,067							
1918	4,510	127,337	137,548	42	2,915							
1919	2,088	39,450	71,482	66	3,516							
1920	677	15,686	25,581	12	878							
1921		42,723	33,655									
1922	1,325	6,620	7,624									
1923		487	31,180		2							
1924	5	3,625	15,437									
1925	41	22,875	99,104		14							
1926	160	7,607	49,609		192							
1927	1,547	22,471	49,283	15	2,385							
Total:												
1904			60,000		7,000			3				
1905	854	7,868	16,344		1,772			7				
1906	679	9,034	32,194		5,116			7				
1907	1,376	12,458	37,775	11	4,271			7	1,120			
1909	526	5,293	20,842	42	13,050			6	1,200			
1910	1,528	12,406	24,031	34	7,936			8	1,440			
1911	1,824	18,585	46,588	32	4,182			8	1,440			
1912	755	13,791	18,159	12	2,640			5	900			2
1913	758	3,607	45,431	9	4,636			6	1,100			1
1914	1,481	6,546	15,568	64	6,281			4	640			
1915	540	2,530	43,627	70	4,675			4	600			
1916	2,100	9,065	107,259	18	4,817			6	850			
1917	9,325	45,902	86,545	40	6,067			13	1,850			2
1918	19,883	174,038	213,581	42	3,800	3	300	19	3,250			4
1919	7,044	71,637	107,798	67	5,185	3	150	11	1,890			3
1920	4,943	29,549	108,356	16	4,548			7	1,130	2	300	5
1921	3,000	42,723	33,655					5	850			2
1922	6,083	10,536	34,923		988	2	100	4	620			1
1923	5,192	13,928	169,164	6	812			12	2,270			
1924	219	23,534	66,521		3,820	2	300	4	600			1
1925	601	223,745	280,038		2,280			14	2,530			1
1926	2,536	72,056	267,006		4,496			11	1,750			2
1927	4,919	38,840	101,004	83	3,433			15	2,850			3

NOTE.—No catch was reported in the years not shown in any division of this table.

Peril Strait has always been known as a pink and chum salmon district. Table 16, showing the catch in the district by localities, discloses that the bulk of the catch consisted of those species, the catch of cohos at Fish Bay being the only exception. Salmon enter the strait from the west through Salisbury Sound and from the east through Chatham Strait. It is probably that a part of the runs coming through the western entrance eventually reach Chatham Strait, but it is not likely that any of

the salmon traveling westward ever go beyond Peril Strait. Fishing in this district has been carried on largely by seines which ranged in number from 3 in 1904 to 19 in 1919 and 15 in 1927. Traps were first used in 1912. Two were operated that year near the eastern entrance and made small catches. Only one was driven in 1913 and none in the next 3 years. The use of traps was resumed in 1917, two being operated, the number increasing to five in 1920, dropping to one in 1922, and none in 1923. Resumption of trap fishing was again gradual until 1927 when three were driven.

Figure 31 shows graphically that the catch of cohos in 1927 was exceeded but six times in 24 years, that the production of chums and pinks in the 3 years from 1925 to 1927 was larger and averaged more than for any similar period in the his-

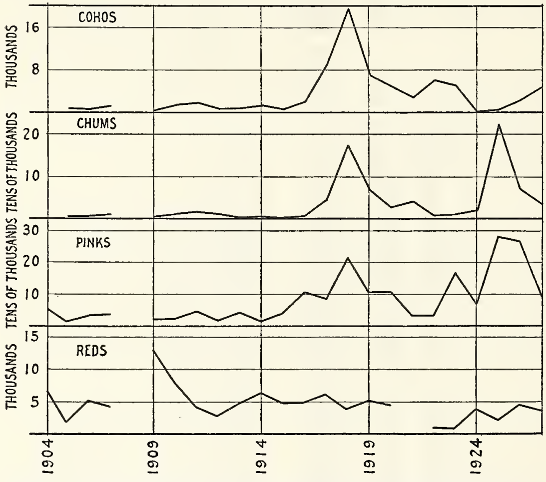

FIGURE 31.—Catch of coho, chum, pink, and red salmon in the Peril Strait district, 1904 to 1927.

tory of the fishery, and that the catch of red salmon in 1927 was below the average for the last 22 years, a difference which may be accounted for by the permanent closing of Hanus Bay in 1925. On the whole the fisheries of Peril Strait appear to be approximately as productive now as ever before although since 1924 all fishing, except trolling, has been prohibited after August 11 in each year.

SUMNER STRAIT DISTRICT

The Sumner Strait district is bounded on the south by a line extending from Cape Decision westward and southward of Coronation Island across Iphigenia Bay south of Warren Island to the southern end of Kosciusko Island at Halibut Harbor; on the north by a line across Keku Strait and Wrangell Narrows at 56° 40′ N. latitude; on the east by a line across Sumner Strait at 132° 40′ W. longitude from Mitkof Island to Zarembo Island. The line of division between Sumner Strait and Clarence Strait extends from Point Colpoys on the north shore of Prince of Wales

Island to McNamara Point on the west shore of Zarembo Island. The total length of the district is approximately 80 miles. The point of division between this district and the west coast of Prince of Wales Island district in El Capitan Passage is at longitude 133° 20′ W. (See fig. 32.)

Sumner Strait is one of the main migration routes of salmon going to the Stikine River, the northern reaches of Clarence Strait, and to all the streams of the

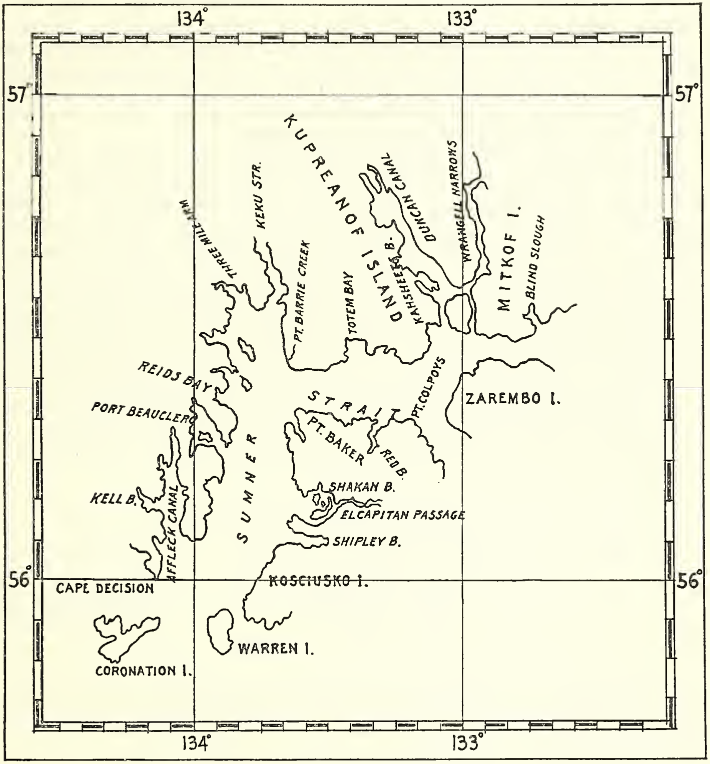

FIGURE 32.—Map of the Summer Strait district.

eastern slope of Kuiu Island, the southern slope of Kupreanof Island, the western part of Kosciusko Island, and the northern part of Prince of Wales Island from Shakan Bay eastward to Point Colpoys.

The Kuiu Island shore is most irregular, being broken by numerous bays from Cape Decision to the south end of Keku Strait. The southern end of this island is, in fact, marked by such deep indentations on both east and west shores as to leave

in several places very narrow isthmuses. Due to these peculiarities, the streams are necessarily short, drain small areas, carry a limited flow of water, and do not maintain large runs of salmon.

The streams of Kupreanof Island and Prince of Wales Island drain considerably larger areas, and under normal conditions, carry a larger volume of water than those of Kuiu Island. For the most part they flow through heavily wooded country much of which is comparatively flat and marshy. It is not an uncommon thing to find streams in these sections that are little more than chains of small lakes. In general the streams are somewhat sluggish, gravel bars are not extensive and are found usually in the lower reaches. Under such conditions, it would be surprising to find large runs of salmon at these localities. Many of the streams, however, are populated by red salmon and to a much larger extent by pinks and chums. The catch of cohos in the district is relatively small; kings are rarely taken.

The history of the salmon industry in this district is not well known, and it is doubtful just when commercial fishing began. It is certain, however, that salmon were taken from these waters by the cannery at Redfish Bay as early as 1892. A cannery at Point Highfield, near Wrangell, began packing in 1889, and while no information is available showing the localities from which its supply of salmon was obtained, it is not unlikely that some streams in this district were fished in that year and regularly thereafter. Between 1899 and 1903 another cannery was opened at Wrangell, three on Wrangell Narrows, and one each at Kell Bay and Shakan, all of which undoubtedly took salmon from Sumner Strait. In all cases where definite allocations were made, such catches have been included in the statistical data for those localities, but after this was done there still remained large unallocated catches in several years which could not be given specific allocation. In order that this record may be as complete as possible, these catches are shown in table 17. All king salmon are omitted, as they can quite properly be included in the Stikine River catches.

TABLE 17.—*Estimated catch of salmon in the Sumner Strait district, 1895 to 1903*

Year	Coho	Pink	Red	Year	Coho	Pink	Red
1895	19, 575	22, 487	33, 400	1900	33, 345	385, 322	130, 098
1896	26, 133	90, 069	30, 884	1901	44, 037	1, 216, 542	151, 873
1897	14, 645	108, 861	27, 083	1902	33, 300	1, 448, 371	122, 514
1898	28, 430	72, 268	28, 802	1903	91, 085	899, 638	138, 807
1899	27, 263	152, 536	37, 188				

In addition to these estimates, red and coho salmon were taken by certain companies and definitely allocated to streams. These data are given in table 18 under the respective years for the following localities: Red Bay, Point Barrie, Shipley Bay, and Kah Sheets Bay.

The Sumner Strait district embraces 44 localities where considerable catches of salmon have been made, 10 of which are on the Kuiu Island shore, 14 on the shore of Prince of Wales Island, 7 on the Kupreanof shore, 3 on the Mitkof shore, 4 on the Coronation and Warren Islands, 5 on Kosciusko Island, and 1 on Zarembo Island. All of these places are shown on either Chart No. 8152 or No. 8200 of the U.S. Coast and Geodetic Survey. Several of them were trap locations, while in others both traps and seines were used. In the first category are Point Amelius, Point Baker, Colpoys Bay, Point Colpoys, Cape Decision, Point Hardscrabble, Pine Point, Cape

Pole, Ruins Point, Twin Island, Warren Channel, and Warren Island; in the latter are Point Barrie, Calder Bay, Shipley Bay, Shakan Bay, and Totem Bay. All other localities in this district were fished chiefly by seines. In correcting errors in the spelling of names and allocation of catches, and in disposing of catches reported from several unknown or unimportant localities, it was necessary to make a number of changes, divisions, and combinations of data to avoid confusion and burdensome detail in the set-up of the table. For these reasons the catch at Point Baird in 1914 was added to that at Point Barrie; that at Bears Paw in 1909 and 1919 and at Bear Creek in 1913 to Bear Harbor catches; that at Calder Creek in 1922 to Calder Bay; that at Aats Bay in 1916, Egg Harbor in 1914, and Carnation Island in 1922 and 1924 to Coronation Island; that at Dry Pass from 1906 to 1927, and from Suter Bay in 1920 and 1924 to Sutter Creek; that at Logger Pass in 1925, Conclusion Harbor in 1923, and Conclusion Island in 1917, 1919, and 1925 to Keku Strait; that at Bluff Island in 1925 and Shipley Bay trap in 1915 to Shipley Bay; that at Shakan Strait in 1909 and 1911–1916 to Shakan Bay; that at Blind Point in 1914, at Falls Creek in 1920, at Scow Bay in 1923, at Cross Creek in 1927, and at Dry Bay from 1918 to 1927 to Wrangell Narrows. Catches reported from Chatham and Sumner Strait in 1914 and 1918, from Sumner Strait and Whitewater Bay in 1919, from Sumner Straight and Frederick Sound in 1914 and 1920, and from Clarence and Sumner Straits in 1913 and 1923 were also divided as equitably as possible and parts were included with the unallocated catches of the district. In addition, catches from 36 other localities were added to the unallocated catches from Sumner Strait. In some cases these places were unknown while in others they were far too general for use as specific localities. They are as follows: Sunshine Harbor in 1908, Rock Stream in 1909, Martin Creek and Reef Bay in 1910, Mountain Creek in 1911, Back Island in 1912, Gill Creek in 1911 and 1913, Seward Point and Warm Cove in 1914, Shoe Bay in 1915, Buoy Bay, Port Baginal and Queen Bay in 1913, Kuiu Island in 1915, 1916, and 1917, Mitkof Island, Hooks Bay, Indian Cove, and Whitewater Pass in 1917, Alvin Bay in 1913 and 1918, Whitestone Creek in 1918, Athletic Islands, Denny Creek, Kam Bay, One Eye, and Sockeye Creek in 1919, Keekan Point, Region, and Will Passage in 1920, Lower Bay and Whitefish Bay in 1921, Sulzer Bay in 1914 and 1922, Baht Harbor in 1923, Todals Creek in 1924, No Name Island in 1920 and 1925, and Aetna Bay in 1926. The total catch of salmon in the Sumner Strait district, as thus determined, is shown in table 18.

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Affleck Canal:												
1913		3,427	42,868		2							
1915	584	3,654	49,378		53							
1917	158				102							
1918			2,220									
1919		2,000										
1920	206	23,704	24,310	6	6							
1921	3	10,840	1,627		199							
1922	13	1,181	22,884									
1923	380	10,806	202,741		552							
1924	3,897	24,404	335,883		1,583							
1925	1,200	21,275	64,842		7							
1926	2,296	70,393	150,577		748							
1927	467	4,427	5,683		795							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Amelius, Point:												
1913		328	8,127									
1915	43		1,684									
1919	128	3,022	17,517	47	426							
1920	104	1,912	1,117		248							
1925	1	650	4,802									
Baker, Point:												
1908		10	22		496							
1910	25		34,360									
1912		1,925	6,852									
1914	365			780								
1915	2,144	658	21,835	2,354	11							
1916	48	1,729	2,366									
1917	35	6	5,362		1							
1918	32	79	3,782		2							
1919	1,767	4,782	28,267	31	4,532							
1920	774	1,168	4,739	89	2,055							
1922	1,971	2,212	12,074	134	1,394							
1925	6	1,907	5,969		28							
1926	2,524	1,291	36,300		4,818							
1927	3,781	7,842	46,952		17,939							
Barrie, Point:												
1892					4,467							
1897					692							
1904	854		39,592		14,538							
1905	1,138		23,586		5,436							
1906	650	2,809	9,121		17,873							
1907		3,689	22,785		9,002							
1908	1,002	1,071	33,878		7,508							
1909	145	774	33,082		11,682							
1910	238	2,363	5,715		10,488							
1911	2,271	5,924	106,918		9,049							
1912	279	1,089	19,504		4,326							
1913	904	348	446		1,825							
1914	4	438	105		3,313							
1915		438	10,362		269							
1916	1,547	3,808	17,477		6,017							
1917	457	1,968	86,447		2,601							
1918	9	9,365	47,951		836							
1919	1,468	26,876	124,002		13,232							
1920	148	10,470	7,141	7	2,280							
1921	356	932	16,302		2,646							
1922	8,083	9,102	103,628	298	7,689							
1923	2,177	3,421	67,404		9,434							
1924	3,443	11,972	42,475	9	8,711							
1925	1,783	6,621	38,507	68	4,765							
1926	5,752	5,692	51,033	10	9,406							
1927	2	117	1,128		996							
Barrier Islands:												
1915		253	4,071									
1918	15	88	2,761									
1927	485	1,281	4,098		711							
Bear Harbor:												
1908			67,404									
1909			6,000									
1910	468	11,470			513							
1912	234	22,153	75,892		12							
1913	14	3,350	82,437									
1915	325	1,161	38,032		3							
1916	363	2,703	1,755		7							
1917	144	10,056	79,168									
1918	129	9,046	32,966									
1919	92	6,526	54,498	2	279							
1920	33	21,267	11,152	1	35							
1921	36	9,649	7,544		128							
1922	155	2,590	5,550		400							
1923	16	605	11,275		10							
1924	226	2,447	70,754		338							
1925	40	6,638	15,444		2							
1926	1,187	12,956	2,452		36							
1927	18	5,560	1,428		91							
Beauclerc, Port:												
1907		5,391	115,283		737							
1908	200	33,505	58,805		2,032							
1909		217	11,746		779							
1910	69	1,846			288							
1911		234	9,955		69							
1912	222	16,613	21,701		22							
1913	182	22,198	121,683		1							
1914		343										
1915	88	5,801	102,478		1,532							
1916	2,278	18,354	49,441	4	3,692							
1917	215	14,109	170,872		281							
1918	691	51,569	30,715		2,584							
1919	926	23,001	28,702		937							
1920	160	20,452	4,752		844							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Beauclerc, Port—Continued.												
1922	622	12, 108	4, 304		88							
1923	869	17, 510	153, 508		1, 301							
1924	189	10, 720	14, 037		61							
1925	1, 499	55, 352	125, 294		201							
1926	1, 732	13, 821	33, 235		363							
1927	1, 113	4, 728	9, 039		2, 958							
Blind Slough:												
1904	301		1, 149		58							
1910	115											
1911	1, 570	3, 072	13, 000									
1912	7, 805	19, 441	289									
1913	6, 275		69									
1916		2, 242										
1917		3, 568										
1918	146											
1919	143	1, 847	178									
1922	4, 626	17, 917	2, 933		50							
1923	2, 842	9, 514	1, 224		77							
1924	2, 144	22, 151	10, 000		1, 682							
Calder Bay:												
1906		7, 687	50, 400									
1907	109	3, 066	38, 264									
1908	1	11, 926	81, 666									
1909	32	7, 092	20, 308									
1910	152	20, 368	22, 260									
1911		3, 872	60, 291									
1912	1, 809	20, 459	16, 988		93							
1913	939	32, 132	85, 825									
1914	195	19, 655	23, 890		12							
1915	30	3, 786	28, 285		141							
1916	1, 192	14, 116	8, 470		401							
1917	154	33, 633	94, 915		170							
1918	757	20, 838	18, 956	1	56							
1919	105	4, 460	2, 402		189							
1920	174	10, 674	7, 702		752							
1922	3, 913	28, 179	26, 984		509							
1923	21	555	3, 952		401							
1924	28	7, 350	9, 604		20							
1925	964	43, 176	84, 243		333							
1926	382	10, 691	19, 242		911							
1927	55	2, 452	7, 068		1, 926							
Castle River:												
1922	521	1, 039	11									
1923	1, 880	52	14									
1924	466	859	246									
1926	1, 150	561	20		1, 138							
Colpoys, Point: [1]												
1913	9, 062	8, 736	441, 558	334	10, 681							
1916	13, 708	8, 336	83, 954	868	25, 531							
1917	3, 916	8, 539	158, 709	660	12, 291							
1918	21, 955	11, 679	100, 080	1, 436	40, 196							
1919	14, 941	9, 013	288, 872		42, 019							
1920	6, 424	16, 859	39, 916	296	39, 284							
1922	13, 548	9, 101	101, 065	213	19, 179							
1923	9, 112	5, 330	328, 378	8	37, 566							
1924	9, 947	5, 474	69, 228	4	18, 490							
1926	5, 279	4, 132	99, 931		20, 266							
1927	1, 751	2, 078	44, 808	7	11, 430							
Coronation Island:												
1914			1, 136									
1916	136	785	2, 369									
1919		4	4, 834									
1920	1	230	1, 642									
1922	2	20	4, 351		4							
1924	442	13, 991	109, 699		253							
1925	1	725	3, 881		2							
1926	17	1, 077	37, 662		29							
1927	2	1, 284	5, 770		20							
Decision Cape:												
1918	10	71	11, 675		305							
1926	2, 198	2, 197	45, 928		428							
1927	3, 526	8, 158	21, 182	10	3, 092							
Douglas Bay:												
1913	701	6, 683	23, 900		786							
1914		3, 195	678	1	216							
1915					42							
Duncan Canal:												
1904	3, 030		8, 340		18, 713							
1905	1, 238		4, 232		11, 284							
1906	2, 325	16, 359	7, 683		6, 109							
1907		4, 169	621		10, 407							
1908	130	238	905		12, 740							

[1] Includes also catches reported from Colpoys Bay for 1916 to 1919, inclusive.

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Duncan Canal—Continued.												
1909	9	5	92		14,237							
1910		1,441	65		12,529							
1911	5,257	2,798	906		3,154							
1912	7,680	8,324	7,179		2,633							
1914	2,073	5,993	5,249		625							
1916	980				1,793							
1917		534	3		361							
1919	3,709	280	127		61							
1922	3,515	12	23									
1923	98	403	32									
Hardscrabble, Point:												
1923	27	16	1,343		184							
1925	5	1,236	6,773		24							
1927	744	965	6,553		1,418							
Hole in the Wall:												
1906			50,500									
1907	231	903	7,689									
1908	733	2,346	43,809									
1909		2,000	6,000									
1910		1,940	4,100									
1912	504	2,029	27,197		14							
1913	522	715	23,579									
1914	126	727	3,739		1							
1915	89	1,988	12,317		32							
1916	3	213	3									
1917	39	1,611	5,556		16							
1918	570	1,067	4,708	1	269							
1919		335	486									
1926	2,737	2,679	24,917		1,020							
1927	458	1,232	4,367		570							
Kah Sheets Bay:												
1897	1,951				4,118							
1914					715							
1915		350	12,000		2,066							
1917	75	3,256	4,309		3,824							
1918	1,117	2,499	19,106		3,210							
1919	5,213	13,847	1,902		6,587							
1920	2,440	26,600	1,875	16	5,428							
1921	89	2,008	12,737		2,836							
1922	3,081	805	1,865		3,259							
1923	454	546	4,576		3,146							
1924	377	817	128		2,531							
1926	2,922	1,147	472		1,844							
1927	113	2,155	4,037		4,055							
Keku Strait:												
1906	428	1,357	146									
1910		897	1,000									
1911	2,777	4,294	86,890		189							
1912	2,960	13,431	59,689		35							
1913	205	47,198	81,422		108							
1914	117	7,496	1,804		146							
1915	966	8,129	79,293		375							
1916	6,900	72,833	129,832	4	489							
1917	1,832	46,656	421,820	19	1,218							
1918	4,066	78,596	348,744	39	6,830							
1919	2,151	18,208	56,365		1,687							
1920	774	7,134	7,099	4	308							
1922	1,069	23,581	8,784		48							
1923	2,260	2,064	32,255		377							
1924	1,410	40,888	27,837		959							
1925	246	52,986	35,028		687							
1926	722	23,230	23,825		407							
1927	2,234	7,038	4,899		402							
Kell Bay:												
1907	1,870	5,323	24,000									
1908			18,556									
1909	18		76,057									
1910		2,601	37,321		3							
1911	21		43,044									
1912	385	3,620	4,790		13							
1913	577	5,717	106,352									
1914		2,063	14,924		1							
1915	16	1,349	17,423		125							
1916	31	11,872	10,577		1							
1917	58	4,232	102,892		1							
1918	1,141	5,699	30,935		120							
1919	286	18,128	50,150		2,178							
1920	841	18,651	28,907	4	307							
1921	4	5,149	2,418		1							
1922	266	7,880	28,789		12							
1923	15	319	20,272		164							
1924	889	41,039	339,720		1,160							
1925	316	23,263	52,424		133							
1926	121	41,830	72,954		383							
1927	202	1,753	1,145	1	203							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Labouchere Bay:												
1920	398	927	1,589	6	585							
1925		994	4,331									
McArthur, Port:												
1912	7	330	6,750		1							
1917	29	4	697		1							
1919		1	10,306									
Pine Point:												
1922	70	4	30		1							
1923	45	34	525	2	235							
1925	1,219	1,185	31,385		2,880							
Pole, Cape:												
1916	87	156	1,998									
1920	1	2	5,467		17							
1927		202	1									
Protection, Port:												
1914	73	442	3,350									
1918	9	2,121	13,413		15							
1920	196	324	1,537		567							
Red Bay:												
1896	4,542				16,348							
1897					12,004							
1898					24,000							
1900					11,243							
1904	1,697		30,091		19,697							
1905	1,119		5,682		20,393							
1906	1,273	28,875	27,874		18,240							
1907	174	17,623	1,008		21,628							
1908	49	11,473	7,625		28,270							
1909	209	19,484	3,511		19,527							
1910		25,015	3,844		34,088							
1911		7,906	3,455		15,170							
1912		8,597	5,384	22	9,898							
1913	307	3,275	48,563		9,171							
1914	600	2,315	5,753		7,657							
1915		727	930		5,683							
1916	2,271	2,860	4,271		10,839							
1917	3,363	5,424	33,141		12,185							
1918	520	4,660	6,493	1	3,581							
1919	752	2,584	7,345	4	6,640							
1920	1,855	2,996	4,683	45	3,738							
1921	35	3,615			553							
1922		1,306	2,182		504							
1923	101	1,019	2,181	1	18,962							
1924	4	82	614		6,850							
1925	43	897	1,125		7,693							
Reid Bay:												
1912		578	526									
1913	4	1,239	34,898		2							
1915		163	11,270		4							
1917	77	1,038	39,001									
1918	1	875	1,297									
1919		113	3,438		534							
1920		145	9		39							
1922	19	255	2,105		37							
1924	28	462	1,095		2							
1925	1,496	16,276	34,678		656							
1926	6	4	1,623		8							
Ruins Point:												
1923	3,288	1,890	92,424		14,294							
1924	15,742	3,787	41,176		7,293							
1925	6,048	7,683	51,845		3,262							
1926	12,441	3,160	55,740		3,201							
1927	1,478	1,454	9,718	2	2,726							
St. Albans, Point:												
1924	113	530	1,427									
1925	2	327	4,715									
St. Johns Harbor:												
1916	132	328	2,078		156							
1922	1,546	211	1,598	25	1,400							
Seclusion Harbor:												
1904	4,756											
1905	1,849		8,716									
1911		125	10,820									
1912	184	16	12									
1913	187	4,291	17,188									
1914		976	276									
1915		173	2,632		66							
1916	117	2,678	13,851		12							
1917	472	36	14,530									
1918		591	628		26							
1919	92	15,150	42,178		471							
1920		5,769										
1922	2	412	4,109		2							
1923	33	1,845	13,566		16							
1924	93	4,378	3,762		74							
1925	38	14,968	23,592		105							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Shakan Bay:												
1906			21,000									
1908			15,540									
1909			6,000									
1911			5,352									
1912		2,413	6,862		58							
1913			2,970		1							
1914		84	3,628									
1915	4	980	13,525		2							
1916	16	4,357	3,744		61							
1918			6,742									
1919	1,063	3,564	15,114		147							
1920	33	2,524	1,837		1							
1922	2,508	18,225	109,669		1,383							
1923	1,808	12,867	166,380		4,361							
1924	808	26,064	97,636	3	2,091							
1925	1,998	8,605	45,289		67							
1926	21	2,844	14,041		8							
Shipley Bay:												
1892					6,762							
1893					5,295							
1897					700							
1898					5,000							
1900					12,000							
1904	460				14,688							
1906	315		139,960		9,627							
1907	1	954	17,178		16,323							
1908		3,682	78,206		14,482							
1909	206	271	99,696		15,401							
1910	325	4,488	25,678		19,965							
1911	25	1,750	60,153		21,702							
1912	2,705	1,495	20,655		18,131							
1913	338	1,847	23,013		9,894							
1914	21	337	2,108	12	1,687							
1915	406	1,507	42,203	4	1,313							
1916	528	4,287	11,057	14	5,522							
1917	3,693	20,975	211,806		6,373							
1918	471	5,800	36,097		2,725							
1919	358	7,893	45,217		6,156							
1920	199	4,357	29,767		6,233							
1921			3,118		4,410							
1922	367	5,763	17,087		1,758							
1923	1,055	2,892	64,078		10,886							
1924	8,108	7,075	70,423		14,989							
1925	191	7,207	51,017		4,125							
1926	187	8,203	94,493		1,468							
1927	35	1,771	2,339		455							
Sutter Creek:												
1906					1,661							
1907	64	29			3,572							
1908	185	22	61		3,665							
1909		171			3,192							
1910	400	2,875	32,230		1,977							
1911	424	879	41,316		4,093							
1912	972	6	334		604							
1913	546	698	2,952		1,198							
1914	441	35	504		385							
1915	1	7	113		945							
1916	429	602	315		2,575							
1917	134	6,755	12,963		2,083							
1918	1,340	284	357		2,168							
1919	495	530	996		243							
1920	3	1,060	2,353		402							
1921			277		1,058							
1922	202	12,280	29,406		8,294							
1923	33	670	6,173		1,146							
1924	10	1,436	1,343		493							
1925	32	14,138	54,305		300							
1926	425	705	15,249		28							
Three Mile Arm:												
1912	140	14,089	7,369									
1913		2,522										
1915		2,319	92									
1918	213	600	6,551		3							
1919	336	2,385	5,110									
1920	167	11,613	1,984		64							
1922	44	6,448	14,239		33							
1923	48	825	8,264		12							
1924	340	3,245	4,131		26							
1925	67	22,573	13,300		26							
1926	13	6,225	15,926		3							
1927	19	404	605		27							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district, 1892 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Totem Bay:												
1904	2,379		24,143		2							
1905	301		437									
1906	839	73	5,997									
1908		363	692									
1910	40	754	911									
1911	49	102	13,541		274							
1913	68	1,122	7,106									
1915	4	18	2,377		20							
1916	27	2,388	5,858	68	628							
1917	363	9,360	9,087		43							
1918	164	9,743	47,962		70							
1919	291	33,623	35,896		184							
1920	484	18,615	7,171		390							
1922	156	487	5,253									
1923	106	1,811	8,869		75							
1924	647	5,256	35,826		465							
1925	451	5,475	17,202	5	653							
1926	4	38	5,674		2							
1927	1	130	145									
Trout Creek:												
1908			25,796									
1909			42,367									
1911		12	52,313									
1912		435	22,139		33							
1914			1,996									
1915	27	53	55,700		9							
1918	5	405	6,435		5							
1920	3	200	3,737		104							
1923			4,883		113							
1924	4,855	2,480	22,844		1,022							
1925	4,088	5,584	73,297		1,257							
1926	113	809	5,304		60							
Twin Island:												
1927	294	1,162	8,555	64	106							
Warren Channel:												
1926	3		8,926		2							
1927	1,126	753	12,760		1,685							
Warren Cove:												
1916	2	870	3,654		9							
1917	42	174	14,371									
1920			6,990									
1927	1	4	179									
Warren Island:												
1914	54	946	6,697									
1915			2,132		154							
1918	15,770	83	9,420	6,236	132							
1919		850	13,528		78							
1920	12	1,167	7,880		70							
1924	1	1	3,687		22							
1925	5	2,148	4,619		391							
1926	23	19	17,680		78							
1927	465	1,418	2,560	7	1,333							
Wrangell Narrows:												
1904	8,858		3,217									
1905	5,863	15,000	20,180									
1906	9,212	3,302	538									
1907	1,296	6,621	400									
1908	1,321	25,991	16,818		146							
1909	1,286	502										
1910	517	4,561	22,164		230							
1911	1,307		1,839									
1912	3,361	4,786	17,962		60							
1913	370		1,960									
1914	5,101		600									
1915		5,991	95,611		2,468							
1916			1,958									
1917	8	742	4,021		168							
1918	162	22,808	69,782		245							
1919	1,594	38,138	17,281		5,103							
1920	2,252	11,220	12,689		239							
1921	5	2,135			1,050							
1922	90	9,324	19,686	1	345							
1923	27	211	4,631		1,040							
1924	238	7,830	64,692		290							
1927	6	1,655	882		853							
Unallocated:												
1904			8,500									
1905	4,590		292,695		57,840							
1907	1,200		5,000		7,803							
1908			6,894									
1909			7,650									
1910		14,952	9,633									
1911		956	39,360									
1912	87	21,147	22,755		1,261							
1913	22	1,288	9,308	1,192	1,074							

TABLE 18.—*Salmon caught and fishing appliances used in the Sumner Strait district 1892, to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated—Continued.												
1914	12,731	110,435	245,447	1,163	55,933							
1915	33,970	39,889	529,010	4,493	51,468							
1916	15,821	21,904	144,019	3,224	11,803							
1917	34,902	37,607	435,802	8,502	9,092							
1918	31,270	43,708	134,176	33,507	16,350							
1919	15,564	63,114	101,605	21,872	13,397							
1920	15,347	150,787	302,246	10,679	21,794							
1921	6,552	6,810	76,161	12,551	18,167							
1922	3,822	1,350	22,946	675	23,990							
1923	9,259	27,774	295,708	1,506	41,537							
1924	2,651	1,954	7,592	2,414	2,017							
1925	25,652	19,158	291,367	10,224	36,662							
1926	12,667	1,852	90,175	2,298	2,253							
1927	21,551	2,730	5,087	31,376	1,599							
Total:												
1892					11,229							
1893					5,295							
1896	4,542				16,348							
1897	1,951				17,514							
1898					29,000							
1900					23,243							
1904	22,335		115,032		67,696	1		8				
1905	16,098	15,000	355,528		94,953	11		8				
1906	15,042	60,462	313,219		53,510	10		6				
1907	4,945	47,768	232,228		69,472			13	2,350			
1908	3,621	90,627	456,677		69,339	1	75	14	2,275	2	230	
1909	1,905	30,516	312,509		64,458	3	280	14	2,375	1	100	
1910	2,349	95,571	199,281		80,081			20	3,795			
1911	13,701	31,924	549,153		53,700			19	4,000			
1912	29,334	162,976	350,829	22	37,194	24	3,455	20	4,205	3	280	2
1913	21,223	147,114	1,166,224	1,526	34,743	18	2,824	11	2,405			2
1914	21,901	155,480	321,884	5,269	67,378	10	1,930	21	3,755	9	605	4
1915	38,697	79,394	1,132,753	6,851	66,781			33	5,448			3
1916	46,616	177,421	499,047	4,182	69,536			32	5,058	9	750	3
1917	50,166	210,283	1,905,472	9,181	50,811			47	8,100	14	1,000	5
1918	80,563	282,274	993,952	41,221	79,728	19	1,705	53	9,365	1	100	4
1919	51,474	300,374	956,316	21,956	105,080	32	3,380	63	12,590			7
1920	33,029	370,827	530,291	11,153	85,745	13	1,325	52	8,323	13	1,040	10
1921	7,080	41,138	120,184	12,551	31,048	3	200	11	1,730	5	1,500	6
1922	50,211	171,792	551,555	1,346	70,379	2	50	49	7,995			7
1923	35,954	102,979	1,494,656	1,517	145,889	3	290	32	5,205	7	375	11
1924	57,096	246,692	1,385,859	2,430	71,422	2	100	67	10,930	5	975	9
1925	47,391	341,047	1,139,274	10,297	64,259			54	8,445			10
1926	54,922	215,556	923,379	2,308	48,908			52	8,505			15
1927	39,927	62,753	210,988	31,467	55,390			32	5,278			22
Caught by lines (included above):												
1912	84											
1913				1,192								
1914	365			780								
1915	21,543			5,419								
1916	5,024			1,536								
1917	34,877			8,502								
1918	23,456			27,536								
1919	15,564			21,869								
1920	262			10,463								
1921	3,710			12,251								
1922	3,550			370								
1923	11,185			34,035								
1924	2,039			2,275								
1925	10,326			9,952								
1927	12,781			31,321								

NOTE.—No catches were reported in the years omitted from each division of this table.

It will be seen from an examination of this table that each locality produced all species of salmon except kings although in several instances the number of reds and cohos was unimportant. The record shows, however, that the distribution was fairly general, and that the first localities fished were those which produced a few thousand red salmon. In this way the streams at Point Barrie, Red, Shipley, and Kah Sheets Bays received early attention. Later the catches included other species which ultimately came to exceed greatly in importance the catches of red salmon although there was no startling diminution in the yield of that species.

Affleck Canal and its arms, Bear Harbor, Kell Bay, and Port McArthur, appears to be the most productive locality as regards pink and chum salmon in the Sumner Strait district notwithstanding the fact that the streams are small. In the long record of its production, 5 years, 1913, 1917, 1923, 1924, and 1926, stand out as exceptionally good pink salmon seasons with 1924 showing a catch of nearly three quarters of a million, approximately three times that in any other year. The catch in 1927, however, dropped to only a little over 8,000 thus reaching an unparalleled low level of production the cause of which cannot be traced. All fishing before 1924 was carried on under the provisions of the law of 1906. In 1924, fishing was prohibited from August 20 to September 9, and yet with this seasonal closing of 20 days the largest catch in the history of the Affleck Canal fisheries was made. In the next 3 years, 1925 to 1927, fishing was prohibited from August 22 to September 14, a period of 24 days, and fishing gear was limited by prescribing the size of seines which could be used. These regulations were continued without change through 1927. A further restriction, prohibiting fishing within 1,000 yards of all streams tributary to Affleck Canal, was imposed in the same year. But the combined effect of all these regulations cannot reasonably account for the apparent serious decline of the pink salmon fisheries as shown in the catches of the two last odd years. A comparison of these catches shows the abruptness of this decline. In 1923 a catch of 234,288 was made; in 1925 the catch was 132,710; and in 1927 it was only 8,256. No explanation of this is found in the unallocated catch of 1927, as the total number of pink salmon in that category for the entire Sumner Strait district was only 5,087. The escapement of salmon in southeastern Alaska in 1925 was conservatively reported as adequate for a satisfactory seeding of the spawning beds while some observers claimed that it was the best they had seen in years. These observations did not apply specifically to the Affleck Canal section but were of general application. The runs of pink salmon were admittedly light in the Sumner Strait district in 1927, streams were low in July and the first part of August and were entered by very few salmon; and there was practically no escapement even after heavy rains later in the season restored the streams to their normal flow. The same condition existed in respect of the chum salmon but not to such a marked degree, as the catches of this species were appreciably smaller in all years than those of pink salmon.

The red salmon stream at Point Barrie enters Keku Strait about 2 miles north of the point. It was probably fished regularly from the year salmon canning began in this section of Alaska, but there is no continuous record of catches until after 1903. Since then it has produced steadily although in some years the catch was extremely light. However, in later years, after fishing was curtailed by laws and regulations the catch has closely approached the average yield when the locality was virgin territory and when fishing was largely in the stream or directly at its mouth. In addition to the seasonal closing, which first became operative in 1924, fishing was restricted in 1926 to waters beyond 1,000 yards of the mouth of the stream, and in 1927 the closed area was extended to 1 mile. These restrictions may have materially reduced fishing in this locality, thus accounting in part for the small catch of all species of salmon here in 1927, yet some allowance must also be made for the effect of the unusual conditions which prevailed throughout the Sumner Strait district in that year. Fair numbers of pink salmon have been reported from Point Barrie, but the catches were marked by wide variability and show no tendency toward 2-year cycles. That these fluctuations were due to natural causes is not necessarily true; to some

extent they may have originated in the exploitation of the runs for commercial purposes.

The catches reported from this locality in some of the later years were not taken entirely from the immediate vicinity of the stream as they include salmon that were captured by a trap near Point Barrie which took fish from the runs to the eastern waters of Sumner Strait. To what extent these data are affected by the inclusion of trap catches cannot be determined, but it may be assumed that the record is fairly accurate in respect to red salmon. The small catches of king salmon at this point presumably came from the Stikine River runs as no kings had been taken in this locality before traps were used. The increased catches of cohos after 1921 may be accounted for in the same way.

The east coast of Kuiu Island is indented by four bays—Port Beauclerc, Reid Bay, Seclusion Harbor, and Three Mile Arm—all of which have made fair contributions to the catch of salmon in this district, chiefly pinks and chums. In each locality wide fluctuations in catches have occurred. At Port Beauclerc, by far the most productive field, all good catches of pinks were made on the odd years although not consecutively. The catches in the intervening seasons, ranging from 1 to 5 years, were undoubtedly comparatively small, indicating either less intensive fishing or smaller runs, but there can be no doubt that, in general, the pinks in this locality show a definite 2-year cycle with the large runs in the odd years. There is no evidence of a diminishing supply. In respect of chums, the variation in catches was not pronounced after 1915 until 1927 when the catch dropped far below any level reached since 1914. With this exception, the records of Port Beauclerc show no apparent reduction in the runs of chums. Coho and red salmon, while never abundant in this locality, are still taken in numbers comparable to those of earlier years, the catch of both species in 1927 having been exceeded only a few times. The situation at Reid Bay and Seclusion Harbor differs little from that at the other localities on this shore of Kuiu Island although the catches have been relatively much smaller; yet in 1925 both places show catches which had been exceeded but once in the history of their fisheries. No salmon were reported from Seclusion Harbor after 1925 and none from Reid Bay after 1926, due undoubtedly to the regulation of 1925 prohibiting fishing within 1,000 yards of the mouths of the streams of both bays.

On the east side of Sumner Strait, indenting the west coasts of Kosciusko and Prince of Wales Islands, are three bays that rank among the best areas in this district. The run of red salmon to Shipley Bay was among the earliest to be exploited in southeastern Alaska. Available records show that it was fished as early as 1892, wholly for red salmon, as no other species was reported from its waters until 1904. Unfortunately, data are incomplete for these earlier years, although it is reasonably certain that salmon were taken here even in the years for which records are not obtainable. Moreover, the catches shown may be only those made by one company so that the full yield is now unknown. From 1904 to 1927 catches were recorded for each year except 1905 when for some unaccountable reason the bay was not listed by any of the packers submitting reports of catches in that year. The production of red salmon held a fairly even level until 1914 when it dropped abruptly to approximately one tenth of the average it had maintained for the preceding decade. No noticeable improvement in the catch was apparent until 1923, 9 years later, when it again approached the level of the earlier productive period. A still better catch was recorded in 1924; but in 1925 it dropped sharply again and shows a progressive decline reaching, in 1927, the lowest point in production of red salmon in the history of the fishery, only

1,468 reds being taken in 1926 and 455 in 1927. It is by no means certain, however, that this decline was due to the depletion of the run. The closed season of 20 days in August and September 1924 and in subsequent years, could have had no effect on the catches as the run of reds was practically over before the middle of August, but the regulation of 1925 closing the bay to all commercial fishing east of a line at 133° 32′ 30″ west longitude, approximately 2 miles from the stream, is probably responsible for the declining catches. It would also seem that the coho fishery was affected in exactly the same way as the catch dropped from 8,108 in 1924, the largest ever known in Shipley Bay, to 191 in 1925 and 35 in 1927. The pink and chum fisheries were but slightly affected by the closing of the head of the bay as the principal stream for these species is outside the closed area. The catch may have been affected, however, by the seasonal closing of 20 days before the end of the runs, although the catch of chums in 1926 had been exceeded but once in 21 years and that of pinks but three times in 22 years. In the light of the data here considered, no depletion of the Shipley Bay fisheries can be assumed.

As to the other localities referred to, Shakan and Calder Bays together show a good annual yield of pink and chum salmon which has been fairly well sustained for 20 years, the peak being reached in 1923. Since then, the catch has fallen off somewhat but has not dropped much below the production of earlier years. Hole in the Wall is a small inlet about 4 miles north of Shakan Bay. It appears to have been fished regularly from 1906 to 1919, with the exception of 1911, and was then abandoned. It was closed to commercial fishing in 1927. The catches reported from this locality in 1926 and 1927 were taken entirely by a trap outside the hole and presumably consisted largely of salmon from the general Sumner Strait runs rather than from runs to this particular locality.

Due to the fact that Keku Strait lies in two districts, it was necessary to make a somewhat arbitrary division of all catches that were allocated only to the strait. The southern part was therefore credited with the catches reported from Keku Strait by companies whose plants were located on or south of Sumner Strait. This method of allocation is not perfect, but it was used as being the most feasible plan in handling these unsatisfactory raw data. The strait was fished in 1906 and from 1910 to 1927, excepting 1921, the most productive years coming between 1915 and 1919. After this period of unusual demands on the fisheries, the catches became much smaller, falling off to the lowest level they had reached since 1914. The lean years were followed by four seasons of better catches, but 1927 was one of the poorest years ever known in Keku Strait. The fluctuations in catches here have no particular significance, however, in showing any depletion of the runs in this locality, as the strait is one of the routes used by migrating salmon to both northern and southern waters.

Other indentations on the north side of Sumner Strait from Totem Bay to Blind Slough are not important fishery localities although fair catches have been made infrequently at all of them; but for the most part the returns have been extremely variable. Duncan Canal was once highly regarded as a producer of red salmon. The catch of reds in 1904 was 18,713; in 1919 it was 61, while none was taken thereafter until 1926, when 1,138 were caught at Castle River. The same situation exists in respect of all other species, so that it would appear that the canal is now the most seriously depleted salmon area in the Sumner Strait district.

Kah Sheets Bay, just south of the entrance to Duncan Canal, is noted for its red-salmon stream and the remarkably uniform catch that has been made there through many years. In 1897, the catch was 4,118; in 1927 it was 4,055. Data for

several earlier years are lacking and also for 1916 and 1925, but these omissions do not necessarily mean that the locality was not fished regularly through all these years. The fluctuations in catch are not significant of exhaustion of the run as, in 1926, when the catch was comparatively low, it was reported that the escapement was exceptionally large. In addition to red salmon, the streams also produce small runs of cohos, chums, and pinks.

Fishing in Wrangell Narrows and Blind Slough covers a period of more than 20 years; catches varied considerably without definite evidence of periodicity. The catch at Blind Slough in 1924 was the largest ever taken from that locality. In the same year the Narrows produced its third largest catch. At best the runs are small and uncertain so that the closing of these waters from Point Alexander to Prolewy Point in 1925 and subsequent years had no important effect upon the fisheries of Sumner Strait.

Red Bay, a small indentation on the north coast of Prince of Wales Island, is one of the oldest and best known fisheries in this district. Its history is similar to that of Shipley Bay and Point Barrie and began with the exploitation of the red-salmon run not later than 1896. The annual yield of this species was well sustained until 1911. The first indication of a failing supply became apparent in 1912 and this became more marked during the next 3 years. The catch improved somewhat in 1916 and 1917, but it dropped even more sharply in the next few years and reached its lowest point in 1922 when only 504 reds were taken. In 1923, however, the reported catch was 18,962 and compared favorably with the number taken in earlier good years. The catches in 1924 and 1925 were again small, and there is no assurance in the record of these later years that the run will regain its former proportions without curtailment of commercial fishing. The bay is small, and salmon have little chance to escape unless fishing is prohibited for long periods; accordingly it was permanently closed in 1926.

As already noted, traps were operated with fair success at several points on Sumner Strait. Those located at Point Colpoys made the largest catches. According to the statistical data, the first trap was driven in 1913 and made a catch of 470,000 salmon. In 1914, 1915, and 1925 no catches were reported, but the unallocated catches of Sumner Strait in those years reached rather high totals and it is not improbable that the bulk of the salmon thus reported came from Point Colpoys. Except as noted, the record is complete from 1916 to 1927. More red, king, and pink salmon were taken here than at any other point in Sumner Strait although this location is near the eastern end of the district. Probably the kings were bound chiefly to the Stikine River, but the other species were in large part destined to the tributaries of Clarence Strait, a fact that was demonstrated by tagging experiments at Point Colpoys in 1926 and 1927. The catch of all species has declined but more markedly in the case of pinks than the other species. Ruins Point is another locality where fair catches were made by a trap which presumably drew largely upon the runs to Shipley and Shakan Bays. Tagging experiments at this point in 1924 and 1925 showed that salmon released here were subsequently taken in these bays and also that there was a general movement northward and eastward through Sumner Strait, a few recaptures being made far to the southward in Clarence Strait and the waters of British Columbia. The somewhat unusual catches of king salmon reported from Warren Island and Point Baker were made by trollers and bear little or no relation to the localities named. Trollers operate in those sections of the strait where king salmon

feed and report their catches as from the point of delivery to the buyers. There is no king-salmon stream in the entire Sumner Strait district.

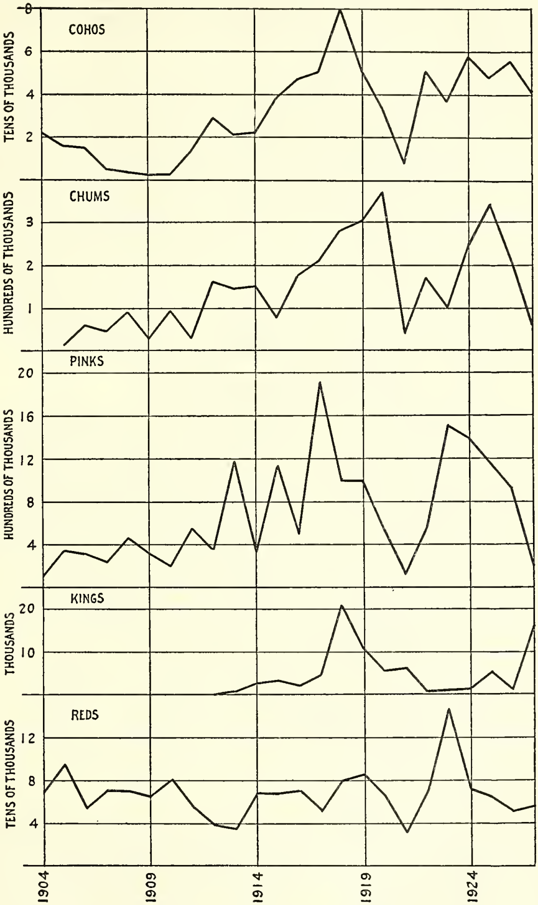

FIGURE 33.—Catch of salmon in the Sumner Strait district, 1904 to 1927.

Sutter Creek is a tributary of Dry Pass which connects Shakan Bay with El Capitan Passage. It supports a small run of red salmon, but the supply apparently had been practically exhausted by 1926. Cohos, chums, and pinks were also taken here, exceptional yields being obtained occasionally, but generally the catches were

not important. Trout Creek is another locality on the west coast of Kosciusko Island, where good catches of pink salmon were made in some years. The record is discontinuous, however, and considerable doubt exists that these larger catches were taken at the stream. It is more probable that they were made by a trap more than a mile from the creek and that the name of the stream was used merely to designate the approximate location of the trap.

The unallocated catches of pink, chum, and red salmon in the Sumner Strait district may be accounted for largely in the operation of traps while those of kings and cohos were taken chiefly by trollers and gill netters fishing in the open waters of the strait and for that reason were not shown as coming from specific localities.

Figure 33 shows graphically the catch of salmon in the Sumner Strait district from 1904 to 1927. The most marked change in the apparent condition of these fisheries was caused by the post-war economic disturbance. It affected all species and reached its lowest level in 1921. The trend of the catches then moved upward again until changing conditions brought about by new laws and regulations from 1924 onward, and the abnormal season of 1927 affected the catch of pink and chum salmon and reduced them to extremely low levels. The other species were not affected to the same extent, nor as suddenly. The production of red salmon is interesting in that it has shown comparatively little fluctuation over a period of almost 30 years.

STIKINE RIVER DISTRICT

The Stikine River district covers the waters of an area which is bounded on the north by a line from Cosmos Point to the point of land on the south side of the entrance to Le Conte Bay, on the west by a line at 132°40′ west longitude extending from the southern shore of Mitkof Island to the northern shore of Zarembo Island, on the south by a line from the north side of Deep Bay, on the east coast of Zarembo Island across Stikine Strait to Point Ancon on Woronkofski Island and thence across Zimovia Strait and Eastern Passage to Babbler Point on the mainland. The eastern boundary is the mainland shore from Babbler Point to Le Conte Bay, practically all of which constitutes the mouth of the Stikine. These boundaries were fixed with a view of covering only the gill-net fishing grounds of this river, and, at the same time, of showing something of the relative importance of this fishery. To that end, only salmon taken by seines and gill nets are considered as Stikine River fish. A map of the district is found in figure 34. Dry Strait, the Stikine flats, and the several mouths of the river constitute the fishing grounds.

The Stikine is the largest river in southeastern Alaska. It rises several hundred miles from the coast in the mountains of western Canada and drains a large glaciated area in consequence of which its waters are highly turbid. Only 25 miles of the lower part of the river lie in Alaska.

The size of the river, perhaps, induced some of the early salmon packers in Alaska to locate canneries near the mouth, under the apprehension that the river supported large runs of salmon, and that proximity to the most important fishing ground was a distinct advantage. In a few years it was evident that the Stikine fisheries alone supplied an inadequate number of salmon for a profitable pack. The first cannery was built here in 1887 at a point 8 miles above the mouth of the river; but 2 years later it was moved to Point Highfield, the northern extremity of Wrangell Island. The second cannery was built in 1889 at Gerard Point directly at the mouth of the river. It operated 2 years and was then merged with the plant at Point

Highfield. In 1912 one more cannery was opened at Wrangell, and eventually several salteries, mild curing stations, and fresh-fish dealers located at Wrangell and carried on a brisk trade with the independent gill netters, seiners, and trollers who operated out of that center. As the independent fishermen gradually monopolized the Stikine River fisheries the established companies extended their efforts to other fields and finally discontinued all gill netting in the district. This change led to the almost total disappearance of gill-net catches in the statistical returns made to the

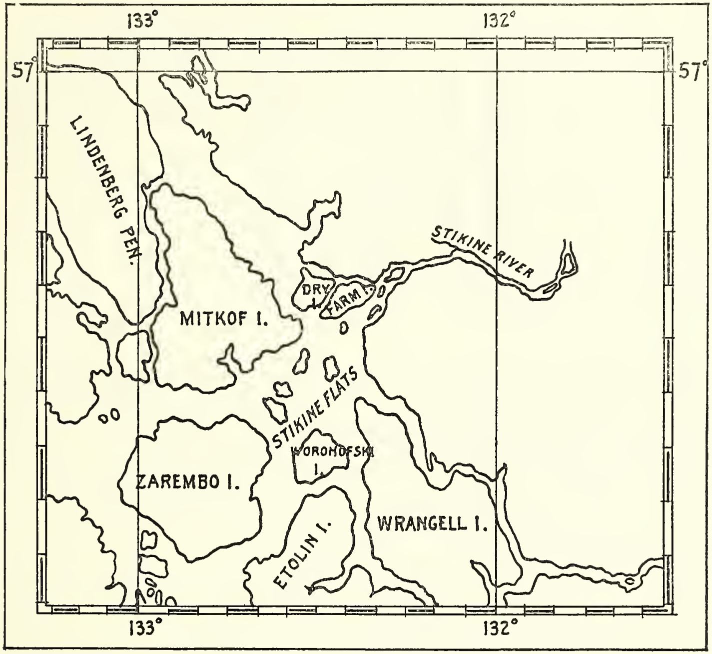

FIGURE 34.—Map of the Stikine River district.

Government. The independent fishermen were operating as many nets as the companies ever did, but they made no report of the number of nets used or the number of fish caught. For this reason no data are available for use in this review showing the number of nets operated in the Stikine district after 1914, except those reported by the packing companies. The catch statistics were obtained only through the companies and dealers. Seines have been used to a limited extent; and traps were tried in 1900 in Dry Strait, at Gerard Point, and in the river, but all of them were complete failures.

TABLE 19.—*Salmon caught and fishing appliances used in the Stikine River district, 1895 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets	
						Number	Fathoms	Number	Fathoms	Number	Fathoms
1895				3,294							
1896	30,000			3,958	30,000						
1897	19,722		20,394	4,680	21,206						
1898				8,565							
1899				12,215							
1901	8,000		7,000	3,269	9,000						
1902	1,157		3,836	3,793	7,961						
1903				181							
1904	31,438		2,082	3,905	29,921	3		2		49	
1905	5,871		25,106	9,270	34,220					41	
1906	14,637	8,563	10,711	2,663	25,292	3				23	
1907	14,868	5,027	8,884	14,871	10,221			2	400	44	7,200
1908	1,600	20,403	49,487	17,572	34,095	1		2	370	93	17,000
1909	15,997	5,614	19,708	22,782	24,470	5	570	1	120	53	10,400
1910	33,233	9,135	7,655	23,113	36,937	3	380	2	300	83	18,800
1911	20,713	5,663	15,119	34,430	22,621			2	380	101	27,650
1912	37,070	1,596	2,331	25,155	5,935			5	980	47	11,450
1913	4,450	19	20,575	30,586	4,987			4	800	39	10,700
1914	24,400	1,676	4,643	11,247	31,183	1	80	5	1,038	16	3,400
1915	13,652	2,502	145,109	6,237	21,184			5	925		
1916	68,104	4,476	89,902	4,853	23,837			5	700		
1917	30,777	24,546	159,473	5,414	55,229			5	1,130		
1918	24,386	5,475	45,107	7,767	6,908			4	800		
1919	44,618	12,010	26,291	12,939	22,898			3	600	1	250
1920	18,265	9,840	2,386	25,216	40,634			2	300		
1921	17,503	1,570	15,467	1,274	13,441						
1922	15,560	1,381	906	13,308	18,662					5	1,400
1923	3,342	3,461	23,972	66,853	33,269					2	700
1924	7,104	4,071	5,860	16,583	32,559						
1925	20,996	5,294	12,612	4,518	21,533						
1926	3,926	7,312	3,530	2,242	5,662						
1927	16,864	1,524	3,332	1,379	4,871						

The total catch of salmon at the Stikine River from 1895 to 1927, omitting 1900, is given in table 19. Moser (1902) gives the catches of the companies at Wrangell in 1900, but makes no segregation of Stikine salmon, so that the data for that year can be used only in the general unallocated catch in southeastern Alaska. There is some doubt as to the reliability of the statistics respecting catches of chums and pinks, which in some years reached surprisingly large totals, particularly in view of the fact that the Stikine is generally understood to have only small runs of these species. The most plausible explanation of these irregularities is that the companies applied the term "Stikine River" to a larger area than that here described and included as Stikine River catches salmon taken from the adjacent waters of Sumner, Stikine, and Zimovia Straits. The catches of coho, king, and red salmon are more nearly correct as these species regularly enter the Stikine and are most heavily fished. There was very slight regulation of fishing in this district before 1925. Beginning in that year, a weekly closed period of 48 hours has been enforced. The length of gill nets was limited to 200 fathoms, but increased to 250 fathoms in the following seasons, and all fishing was prohibited from June 21 to July 5. In 1926 and 1927 the seasonal closing extended from June 10 to June 30, but it did not apply to trolling.

Considering its size, the Stikine River is not a large producer of salmon, and its fishery value suffers by comparison with many smaller streams even in the same general region. Its chief importance lies in the king salmon fishery which, however, cannot be fully estimated without taking into account the effect of trolling throughout the length of Sumner and Clarence Straits and along the west coast of Baranof and Prince of Wales Islands. It is also possible that Stikine king salmon approach the river through Chatham Strait and Frederick Sound, but in smaller numbers than through the southern approaches. In some measure the same conditions affect the

cohos, as they are found with the king salmon on the feeding grounds and constitute fully half the catches of the trollers on these widely scattered fields. The recorded catches in this district do not, therefore, accurately reveal the true condition of the fisheries and the fluctuations in catches at the mouth of the river and the falling off in recent years cannot be taken as definite evidence of serious depletion.

WEST COAST OF PRINCE OF WALES ISLAND DISTRICT

This district embraces all the waters of the west coast of Prince of Wales Island from the boundary of the Sumner Strait district at 133°20′ west longitude at the northern end of El Capitan Passage southward to Tlevak Narrows, all the intervening islands, the eastern and southern shores of Kosciusko Island, and the entire west coast of Dall Island to Cape Muzon, comprising a total length of approximately 115 miles. (See fig. 35.) The several passages and channels between the islands, and the many small bays of the region, mark this as probably the most intricate shore in all Alaska. The islands of the district are rugged and for the most part their shores are bold and rocky. No rivers or very large streams are found here. There are innumerable small streams, however, many of which are the outlets of lakes. The salmon runs provide a varied fishery of which the pink salmon is the predominant species.

Salmon canning began in this district in 1878, simultaneously with the beginning of packing at Old Sitka. The first cannery was located at Klawak, superseding a saltery which had existed there for several years, and in 1927 it attained the distinction of having an unbroken record of packing for 50 years. Salmon salting was carried on to a limited extent in other localities soon after this cannery was established, notably at Sarkar Cove, Holbrook Creek, and Shinaku Inlet. No other canneries were built or operated in this district until 1911, when the first floating plant made its appearance and anchored in the vicinity of Waterfall where a cannery was built a few years later. The Klawak cannery was, therefore, the sole occupant of the district for a period of 33 years although canneries in adjacent districts frequently took salmon from the more noted red salmon streams.

Details of the catches from 1878 to 1895, inclusive, are not available, so that there is now no means of knowing how many salmon of each species were taken in these years or the localities from which they came, except as Moser recorded the catches at Klawak and a few other localities from 1886 to 1900 by one company. The pack for these earlier years is shown in table 20.

TABLE 20.—*Pack of canned salmon at Klawak from 1878 to 1895*

Year	Cases	Year	Cases	Year	Cases
1878	5, 402	1884	6, 189	1890	10, 188
1879	6, 675	1885	8, 428	1891	9, 256
1880	6, 539	1886	7, 680	1892	10, 194
1881	8, 977	1887	9, 562	1893	12, 595
1882	11, 501	1888	12, 325	1894	14, 455
1883	8, 240	1889	11, 370	1895	12, 228

It is probable that these packs were largely, if not wholly, composed of red salmon, and that the larger part of the catches came from the Klawak stream. Not until competition for red salmon developed was much attention given to the other

species, although the pinks were the most abundant and were present at the red salmon streams as well as numerous others.

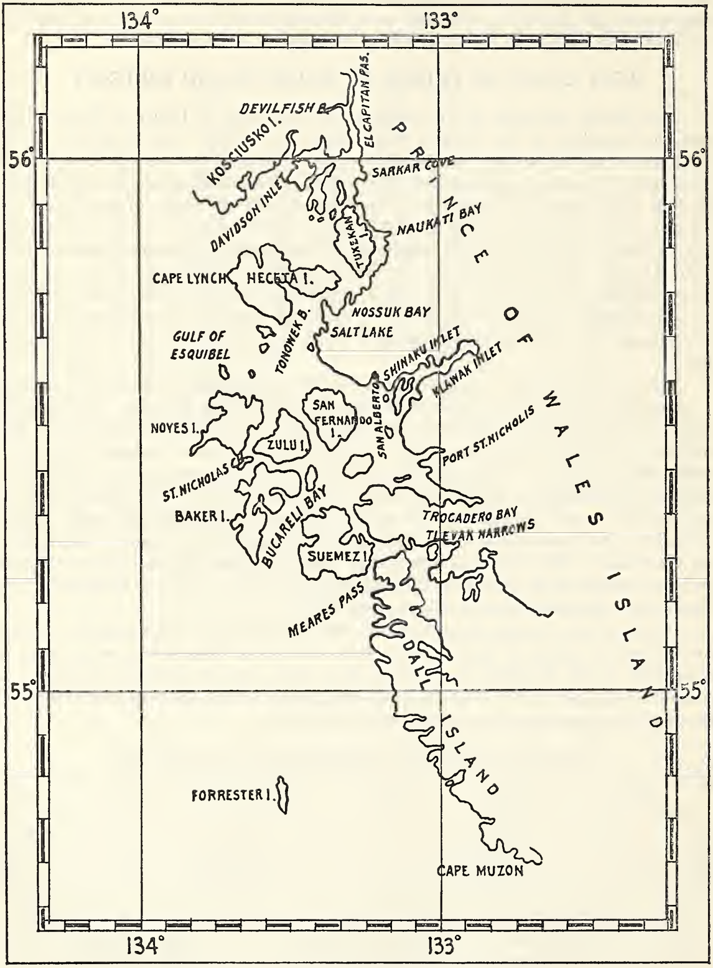

FIGURE 35.—Map of the west coast of Prince of Wales Island district.

The early history of the fisheries of this district indicate that seines and gill nets were used exclusively from 1878 through 1911 and that traps were introduced in

1912 for the first time, 11 being operated that season. No pronounced increase in the number of traps occurred until 1922, while in the same period the number of seines remained fairly constant. After 1924, the number of traps increased steadily from 22 in 1924 to 60 in 1927. In the same period, the number of seines dropped from 73 to 54. These figures indicate a striking change in the character of the fishery, so that what had been exclusively a seine and gill net fishery for many years rapidly became predominantly a trap fishery. The number of canneries had also increased to eight in 1927, with probably an equal number located outside the district which drew upon its resources. Trollers also made their appearance in these waters and in a few years developed coho and king salmon fisheries of considerable importance.

The first regulation of the fisheries beyond that provided in the general law of 1906 was imposed in 1918 by closing to commercial fishing all streams less than 500 feet in width, and prohibiting fishing with movable appliances within 200 yards of the mouths of the streams and with fixed appliances within 500 yards of the mouths. These regulations were continued in 1919 and made applicable to all streams regardless of their width. The next change occurred in 1921 by removing the exception in favor of movable appliances and putting them on the same basis as fixed appliances. After the law of 1924 became effective, a closed season of 61 days was promptly imposed by prohibiting all fishing, except trolling, from midnight August 25 to midnight October 31. In 1925, the seasonal closing covered the entire year except from midnight July 14 to midnight August 22 and from midnight September 14 to midnight October 15. Sarkar Cove was also permanently closed. The regulations of 1926 and 1927 continued the seasonal closings without change and in addition limited the size of seines and permitted the use of traps in certain designated localities. Naukati Bay and approximately 3 miles of the eastern end of Trocadero Bay were included among the areas permanently closed to salmon fishing. In 1927 these closed seasons and areas were maintained with the further prohibition of traps in that part of Tuxekan Passage lying between 55°41′ and 55°52′ north latitude and in all waters within one half mile of the southern point of Tuxekan Island. All waters within 1 mile of the mouth of Staney Creek were also closed. The probable effect of these regulations will be discussed in connection with the review of the statistical data presented in table 21, showing by localities the total catch of salmon in this district.

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Addington, Cape:												
1925	215			1,795								
1926	87	12	4,686		267							
1927	290	60	2,121	8	3,624							
Anguilla Island												
1926	212	468	4,767		336							
Arboleda, Point:												
1924	1,496	2,724	70,081		1,876							
1925	2,191	16,879	26,781		1,311							
1926	1,853	5,239	45,870		703							
Augustine Bay:												
1914					190							
1924					332							
1926					358							
1927					208							
Baker Island:												
1912		19,662	19,014		1							
1913			5,529									
1914	329	6,624	7,459		3							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Baker Island—Continued												
1915	321	8,535	6,915									
1918	57	2,215	4,233									
1919	490	15,529	21,476	50	7							
1920	77	11,319	24,540		9							
1923	309	5,611	20,647		53							
1925	3,553	46,778	59,483	9,511	1,823							
1926	3,084	17,933	66,066	4,799	1,573							
1927	4,791	4,352	20,057	10,252	2,166							
Bartolome, Cape:												
1925	244			1,225								
1926	1,920			1,800								
Bazan, Port:												
1919		120	929		739							
1924	112	220	3,584		315							
Big Salt Lake:												
1919	4,801	18,061	24,694		281							
Blanquizal Island:												
1926	1,576	6,117	70,469		2,263							
1927	473	1,157	9,075		2,028							
Bobs Bay:												
1913			10,756									
1914	118	3,500	7,701									
1926	5	1,785	2,235		22							
1927	1	502	9		5							
Bocas de Finas:												
1915	186											
1922	5,673	7,597	86,415		9,403							
1923	2,437	1,005	38,691		1,234							
1924	794	1,962	12,193	38	2,827							
Bucareli Bay:												
1915		9,761	9,607		35							
1916	2,437	16,991	4,343		7							
1917	1,407	16,738	56,121		11							
1919	13	270	6,926		2							
1922	8,135	63,408	133,793	17,630	51							
1923	35	388	7,096		128							
1924	1,980	66,587	119,394	11,043	1,647							
1925	69	7,200	1,600		500							
1926	1,954	7,437	46,343		1,296							
1927	2,913	2,653	9,564	12	1,629							
Cabras Island:												
1927	166	68	120		156							
Caldera, Port:												
1926	14	1,078	3									
Camp Taylor:												
1907		718	103,285									
1908			27,642									
1909		2,358	96,316									
1910	2		23,139		51							
1911			6,118									
1912	282	785	26,031		16							
1913	78	1,321	4,400									
1914		567	2,008									
1915	7	432	7,661		19							
1920	8	556	1,747		3							
1923		954	1,187		7							
1925	54	10,772	87,274		51							
1926	58	1,299	14,122		49							
1927	42	907	916		28							
Cangrejo, Point:												
1926	254	1,562	10,981		197							
Cap Island:												
1913		2,021	284									
1927	97	357	1,512		74							
Clam Island:												
1922	303	1,572	57,175		2,873							
1923	1,049	1,665	42,239		3,290							
1924	484	2,155	134,007		5,532							
1925	266	1,547	12,518		3,181							
1926	346	2,088	65,482		684							
1927	172	192	427		486							
Cocos, Point:												
1925	1,461	5,984	21,067	4	892							
Craig:												
1920	1,981	16,163	100,387	1,770	2,393							
1921	290	8,581	15,099		32							
1922	2	748	474									
1924	1,306	9,407	36,887		696							
Cruz Island:												
1919	4	2,967	1,154									
Culebra Island:												
1927	161	117	837		130							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Dall Island:												
1909	64				1,903							
1911	3		70,772		20							
1913			15,965		63							
1914		3,931	6,465		477							
1915		2,962	10,874									
1916	1,027	7,062	8,928		50							
1917	1,665	22,392	44,193		666							
1918	846	316	1,172		1							
1920	152	4,924	305		1							
1925	2,426	58,467	41,786	587	1,624							
1926	205	8,165	30,578	3	605							
1927	40	80	300		75							
Davidson Inlet:												
1913			45,000									
1915		1,854	7,930		38							
1917	565											
1918	1,561		8,284	135	32							
1926	7	2,091	3,070									
Dead Tree Point:												
1926	1,836	3,270	32,373		1,965							
1927	623	734	1,789		703							
Derrumba Landslide:												
1925	3,780	14,302	165,287		4,018							
1927	1,900	1,952	7,054		1,349							
Desconocida, Point:												
1923	5,051	5,721	235,363	5	9,723							
1924	1,827	5,609	51,748		3,571							
1925	1,841	7,857	127,325		1,944							
1926	575	5,194	35,000		725							
1927	1,038	3,134	16,790		2,016							
Devilfish Bay:												
1906			60,390									
1907		2,139	186,503									
1908			12,947									
1909		2,101	89,800									
1911		1,522	169,416									
1912	2	3,115	15,140		11							
1913	19		16,120									
1914		960	2,296		2							
1915	15	538	16,304		11							
1917		2,444	19,500									
1919		74	5,876		4							
1924		6,188			5							
1925	15	1,011	9,330		67							
1926	13	3,864	17,283		43							
1927	9	720	2,432		227							
Dolores, Port:												
1912	91	4,330	1,918		2							
1914	22	4,622	4,556		2							
1918		137	501		6							
1923		38	2,304									
1925	64	1,958	3,538		9							
Eagle Point:												
1923	2,104	1,177	55,616		3,207							
1925	2,077	8,652	83,260		2,094							
Edna Bay:												
1910	61	2,341	56,973		87							
1912	101	589	23,850		10							
1914	1	48	1,578									
1915	40		26,678		133							
1919	64	3,906	15,238		9							
1920	38	14,938	19,282		103							
1922	213	44	6,949		2							
1923	24	3,372	18,800		57							
1924	5,725	9,813	62,188		1,163							
1925	4,162	7,951	109,467		918							
1926	725	4,387	34,142		206							
1927		83	3									
El Capitan Passage:												
1904					13,000							
1906			51,300									
1907	274	3,219	30,408		350							
1908		7,646	46,315									
1909		1,445	28,895									
1910		496	31,122									
1911		1,874	158,864									
1912	382	2,500	32,923		491							
1913	130	5,848	33,781		1							
1914	57	484	914		1							
1915	121	1,962	45,763		191							
1916	774	3,600	2,362		60							
1917	233	9,320	48,675		115							
1918	659	5,379	9,005		230							
1919	259	6,222	39,760		392							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
El Capitan Passage—Con.												
1920	26	1,589	7,106		30							
1923			1,000									
1924	2,266	26,607	72,260		7,230							
1925	163	39,795	228,388		1,953							
1926	34	5,472	83,473		159							
1927	481	11,675	13,037		676							
Eleven Mile Creek:												
1912	19	2,269	18,959		22							
1918		50										
1919			6,019		8							
1923	341	2,402	30,871		215							
1924		1,363	434									
1926	872	12,070	59,906	4	635							
1927		373										
Esquibel, Gulf of:												
1912				1,000								
1913	4,392	583	20,536	577	526							
1915		1,996	366									
1922		3,613	18,700									
1924	9,136	8,608	76,613	9,135	81							
1927	1,025	1,926	25,105	15	416							
Esquibel Island:												
1927	242	93	179	18	223							
Essowah Creek:												
1926	1	48			189							
1927					158							
Estrella, Port:												
1914		3,201	325									
1915		612	1,108									
1916	42	554	18									
1923		97	2,513									
1925	6	412	3,576		6							
Felix, Cape:												
1918			31,463									
1919	101			68								
1922			10,070									
1923	3	776	8,891		3							
1925	166			1,107								
1927	3				354							
Fish Egg Island:												
1910				17,030								
1911	4,279	2,400	5,700		720							
1912	6,292	7,255	290	2	80							
1913	7,500	6,250										
Flores, Cape:												
1925	46	1,302	2,997									
Forrester Island:												
1912	6,815			22,380								
1913				20,689								
1914	18,150			82,122								
1915	20,833		7	13,356								
1916	10,317			593								
1917	7,094			17,134								
1918	16,117			11,463								
1919				2,500								
1925				1,160								
1926				920								
Gooseneck Harbor:												
1913		15	12,226		47							
1919	2	171	3,262		21							
Halibut Harbor:												
1914	30	207	16,696		29							
1919	2	7	15,964		2							
1924	8	1,695	24,401		147							
1925		25	2,920		10							
1926		1,083	7,017		8							
1927	16	4	77		73							
Heceta Island:												
1917		119	8,446		58							
1920	140	753	3,518		61							
1925	250	7,000	62,709		375							
1926	5,214	13,760	120,591	1	6,268							
1927	1,958	3,135	13,855	29	1,728							
Hermagos Islands:												
1926	371	5,650	35,758		441							
Holbrook Creek:												
1903	9,486				3,600							
1909			19,352									
1925	450	8,000	69,409		1,250							
Ildefonso, Point:												
1914		2,083	2,029		1							
1915	437	9,084	13,595		70							
1918	265	422	861									

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Ildefonso, Point—Continued												
1919		28	2,629		14							
1924	590	3,717	61,932	20	2,336							
1925	1,333	18,755	72,525		1,207							
1926	592	4,119	62,555		1,126							
1927	197	189	578		277							
Incarnation, Point:												
1926	155	150	1,956		69							
Iphigenia Bay:												
1923		153	6,729									
1924	2,483	9,783	98,450		3,662							
Karheen:												
1914	937	6,513	13,421	58								
1915	56	297	3,273		10							
1917		1,477	1,331		6							
1918	432											
1919	378	21,491	28,508		2,179							
1920	413	9,753	13,621		180							
1921					399							
1922	10,297	133,709	204,584		8,579							
1923	44	293	14,709		63							
1924			495									
1925	267	28,344	87,043		722							
1926	168	141	3		9							
1927	6	1,129	151		1							
Klawak Inlet:												
1886					5,424							
1887					41,180							
1888					62,602							
1889			92,094		19,361							
1890					49,689							
1891					58,096							
1892					40,555							
1893					33,166							
1894					34,722							
1895					40,526							
1896	2,667				37,172							
1897					12,764							
1898	11,664		65,000		36,881							
1899	5,000		53,000		75,000							
1900	500		200,000		31,000							
1904	23,156		130,940		74,437							
1905	9,216		170,506		50,097							
1906	11,506		111,040		43,526							
1907	112	627			40,286							
1908	19,498	17,562	630,531	9,200	33,819							
1909	19,135		551,833		49,520							
1910	6,801	95,562	467,030		51,203							
1911	34,071	34,245	782,042		55,912							
1912	6,964	44,104	80,029		47,521							
1913	4,632	52,861	177,401	79	17,311							
1914	12,071	128,698	283,325	3	28,034							
1915	12,259	96,258	211,921	40	24,922							
1916	17,837	72,770	117,693	102	24,263							
1917	12,905	63,057	604,884	2	39,527							
1918	15,076	36,152	475,092	1,081	36,179							
1919	10,180	194,759	545,327		66,964							
1920	8,004	182,960	111,469	16	35,849							
1921	692	1,641	155,659	5,700	21,474							
1922	9,721	62,520	523,665	94	27,198							
1923	12,805	31,945	361,201		22,863							
1924	2,930	57,276	555,380		30,765							
1925	5,994	143,264	119,554	973	18,469							
1926	7,539	105,233	741,041		10,734							
1927	502	10,473	5,670	8	10,012							
Liscome Bay:												
1925	19	199	3,485		203							
1927		2	5		315							
Little Skookumchuck:												
1909	69		19,627									
Lookout, Cape:												
1918			2,106		645							
1919	21	105	2,014		152							
1923	19	420	5,615		25							
Lulu Island:												
1925		811	1,151		2							
1926		3,630	5,046		4							
Lynch, Cape:												
1914				22								
1915	91	1,113	15,086	169	144							
1916	3,102	5,112	16,919	552	3,539							
1920	11	52	1,029									
1922	621	1,768	18,152		4,732							
1923	667	748	31,171	29	1,383							
1924	2,332	6,246	46,781		3,642							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Manhattan Arm:												
1927					113							
Marble Creek:												
1907	561											
1908	241											
1909			8,666									
1917	400	72	64									
Meares Passage:												
1912	2,441	4,362	38,643	14	2,020							
1923	14		2,166		24							
1926	8	22	2,778		16							
1927	42											
Naukati Bay:												
1906			40,200									
1907	264	9	78,916									
1908	1,430	1,211	64,209		1,203							
1909	532		34,097		116							
1910	9	3,404	42,652		193							
1911					675							
1912	741											
1913	1,858	7,585	40,451		969							
1914	310				243							
1915	178	473	4,350		2							
1920	29	2,138	5,019		21							
1923					24							
1924	177	2,222	3,038		448							
1925		226	3,153		7							
Nossuk Bay:												
1910		7,058	42,113									
1913	346		33									
1915	184	5,452	8,946		280							
1916	127	1,767	4,178		11							
1917	12	4,638	23,388		26							
1918	5	773	6,351		43							
1919	50	1,240	1,610		13							
1920	1	243	2,044		2							
1923		267	3,011		2							
1924		1,525	1,285									
1925	1,071	42,027	42,894		242							
1926	175	460	188		1							
1927	2	2,892	218		26							
Noyes Island:												
1912	610	3,461	16,781	620	1							
1913	1,675		5,600	13,549	1							
1914	798	3,560	5,026	22,365	29							
1915	945	22,973	38,726	15,254	2							
1916	939	12,042	18,002	1,698								
1917	50,540			16,044								
1918	15,584	567	3,409	4,662								
1919	20,136	230	716	19,673								
1920	616	1,978	10,033		7							
1923	55	1,111	7,426	16,200	1							
1925	3,478	2,396	863	17,092	4							
1926	9,487	14,443	193,223	9,331	5,802							
1927	17,675	1,494	4,522	84	2,709							
Palisade Island:												
1926	1,880	3,755	28,572	4	504							
1927	1,171	660	2,650	22	509							
Portillo Channel:												
1916	369	9,876	4,523		35							
1923	4	62	3,044		5							
1924	7	2,506	5,518									
1925	230	19,547	14,716	1	132							
1926	361	20,107	18,731		291							
Providence, Point:												
1925	1,482	7,577	62,936	11	1,162							
1927	394	1,235	7,181		669							
Real Marina, Port:												
1914	2	2,090	4,636									
1917	1,603	6,803	8,964		480							
1925	877	38,684	15,415		6							
1926	80	7,285	10,044		45							
1927		115	72									
Refugio, Port:												
1912	1	1,309	4,414									
1913	170	1,033	14,035									
1914	189	28,046	3,767		8							
1915	50	11,083	9,542									
1916	433	8,560	617		6							
1917		12,405	12,980		4							
1919	8	697	732		2							
1922		1,543	4,323									
1923	2	46	3,389									
1926	47	2,319	82									

Table 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Remedios, Point:												
1925	1,544	3,047	31,302		732							
Roller Bay:												
1924	2	211	7,891									
1926		840	2,800		3							
Rosary, Point:												
1914		2,291	3,284									
St. Ignace Island:												
1926	652	6,263	45,275		482							
1927	2,399	3,051	12,501	10	1,157							
St. Joseph Island:												
1927	321	159	410	8	139							
St. Nicholas Channel:												
1916	15,091	1,791	531									
1920	10	1,206	1,202		2							
1922	91	138	517		46							
1923	45	257	11,474		290							
1925	52	2,624	6,556		6							
1926	235	8,874	10,094		4							
St. Nicholas, Port:												
1913					83							
1914	5	1	438		6							
1915			1,888		2,149							
1922	404	27	2,906		144							
1923	1,006	106	4,118									
1925		726	226									
1926	276	6,316	648		13							
1927	14	806	1,038		44							
St. Philip Island:												
1915		506	796									
1923	5	148	7,329		1							
1925	264	1,620	3,744		5							
1927	697	1,070	5,627	15	627							
Sakie Bay:												
1914		349	12,036									
Salt Lake:												
1912	1,284	226	2,310									
1913		22	150									
1914		286	2,325		2							
1916	600		11,000	825								
1920	3	2,185	16,990		98							
1922	77	1,839	19,388		145							
1923	409	1,510	6		2							
1925	122	9,797	6,259									
1926	1,062	7,140	6,576		25							
1927	48	2,005	623		25							
San Alberto Bay:												
1914	1	893	1,110		10							
1919	350	8,261	45,260		674							
1923	161	292	16,106		450							
1924		696	10									
1925	6	2,756	2,544		1							
San Antonio, Point:												
1920		652	1,349									
San Antonio, Port:												
1913		507	10,960									
1914	25											
1923	7	1,064	5,776		1							
1925	190	10,415	1,723									
1926	21	5,812	164									
San Christoval Channel:												
1913	161	432	914	8	2							
1916	743	3,515	1,192		1							
1917	1,019	1,270	25,119		23							
1919	1,028	12,569	59,540		733							
1920	1	1,433	2,479		36							
1926	1,070	1,975	99,482		2,141							
1927	1,802	2,975	13,482	30	1,713							
San Fernando Island:												
1914	493	10,083	11,826		46							
1915	9	1,171	4,141		1							
1917	64	4,160	11,301		11							
1918	67	730										
1919	1,169	22,407	14,143		17							
1920	101	5,017	5,869		6							
1923	40	3,131	13,392		4							
1925	22	10,646	13,379		92							
1926	47	2,036	3,830		4							
1927	125				61							
San Francisco, Point:												
1920	12	2,666	12,883									

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
San Juan Bautista Island:												
1916		3, 160	726		76							
1925	550	12, 100	18, 528		632							
1926	665	3, 224	28, 665	1	561							
San Lorenzo Island:												
1927	157	113	322	14	88							
Santa Cruz, Port:												
1913	31	825	17, 769									
1914		2, 485	6, 559		2							
1915	6	1, 340	3, 892		90							
1916	3	1, 499	685		4							
1922	2	1, 672	6, 506									
1923	1	250	6, 797									
1926	69	2, 953	16, 814		94							
Santa Gertrudis, Point:												
1927	2, 416	1, 517	1, 756	144	1, 081							
Santa Rosalia, Point:												
1927	824	786	2, 844	38	556							
Sarheen Cove:												
1907	267	714	77, 829		143							
1908	1	105	19, 908		206							
1909			6, 000									
1910					263							
1911	21		15, 113		821							
1913	13	350	10, 877									
Sarkar Cove:												
1887					6, 476							
1888	14, 528				6, 834							
1889					11, 555							
1890	15, 331				16, 267							
1891	9, 033				35, 033							
1892	4, 700				24, 024							
1893					9, 797							
1894					12, 678							
1895	3, 830				11, 636							
1896	9, 643				20, 480							
1897	8, 207				21, 667							
1898	10, 423				24, 974							
1899	7, 000				36, 000							
1900	12, 000				26, 021							
1901	13, 000				11, 000							
1902					12, 500							
1903	6, 000				4, 500							
1904	16, 953				51, 946							
1905	14, 250		7, 000		33, 025							
1906	2, 689				31, 857							
1907	2, 400				34, 500							
1908	7, 807				33, 120							
1909					14, 627							
1910	2, 975	23	221		16, 175							
1911	7, 829	12	95, 802		69, 210							
1912	6, 723	532	20, 897		28, 651							
1913	337		9, 038		662							
1914	10	1, 449	1, 099		4, 540							
1915	4	208	5, 151		2, 866							
1916				1	110							
1917	6, 991	2, 270	23, 681		13, 252							
1918	4, 340	105	5, 217		16, 991							
1919	5, 250	668	24, 144		20, 222							
1920	2, 814	1, 926	5, 521		12, 640							
1921			10, 922		27, 242							
1922	1, 646	419	8, 396		18, 052							
1923			2		144							
1924	950	4, 184	3, 036		12, 996							
1925	22	19	28		837							
1926	300	451			400							
1927	121	750	112		1, 274							
Sea Otter Harbor:												
1915	59	3, 815	5, 915	158								
1919	204	1, 091	9, 867		64							
1922	6	6	1, 711		13							
1923	47	2, 883	39, 896		274							
1924		2, 377	7, 941		1							
1926	5	2, 032	3, 100		214							
1927	6	44	92		151							
Sea Otter Sound:												
1908			156, 000									
1913	909	4, 625	215, 870	182	1, 181							
1914		470	29, 048		367							
1915	3	2, 192	76, 225		575							
1916			30, 190		2, 042							
1917	741	6, 680	18, 168		22							
1918	23											
1919	1, 073	19, 703	73, 521	105	178							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Sea Otter Sound—Contd.												
1920	18	1,749	3,462									
1923	1,671	13,747	117,270		1,343							
1924	457	32,505	20,019		871							
1925	217	7,485	25,798		25							
1926	2,301	5,300	30,692		544							
Shinaku Inlet:												
1903	2,100		89,000									
1904	240		7,920									
1912	41	22,179	12		71							
1913	133	1,309	150,670		1,038							
1915	75	5,200	97,685		525							
1920	80	2,119	3,477		48							
1921			8,464		93							
1924	199	13,261	8,126		211							
1925	192	21,081	108,485		114							
1926	32	5,928	13,047		40							
1927	4	1,712	350		14							
Skookumchuck:												
1906			92,000									
1910	570		1,228		602							
1911	428		23,280		194							
1912	558	4,731	11,216		71							
1915			2,665									
1919	351	3,511	3,128		3							
1926	5	640	840		211							
1927	261	320	1,393		461							
Snail Point:												
1926	189	2,703	13,356		503							
Staney Creek:												
1904	12,276											
1905	12,598											
1907	280											
1908	5,574		50,056		870							
1910	7,420	696	53,991		267							
1911	3,239	527	467,620									
1912	9,959	17,176	66,089		499							
1913	11,816	64,903	176,344	9	504							
1914	809	23,418	4,537		1,048							
1915	1,298	11,269	157,371	13	975							
1916	7,120	13,930	15,755	33	378							
1917	1,505	20,781	59,998		501							
1918	5,093	25,962	16,957		954							
1919	4,912	16,231	119,908		1,420							
1920	1,829	13,922	25,788	6	916							
1921			13,412		108							
1922	3,682	60,835	116,268		286							
1923	5,572	14,187	192,619		1,161							
1924	409	24,453	58,611		1,313							
1925	3,037	83,660	126,846	1	664							
1926	572	23,587	93,191		641							
1927	62	18,304	3,938		753							
Steamboat Bay:												
1916	6,167											
1918	14,691		1,984									
1925	133	3,487	3,940	882	12							
Suemez Island:												
1914		4,692	12,318									
1915		1,134	2,414		5							
1916	8	1,312	788									
1917	16	1,653	2,810									
1918	170	2,178	2,060									
1919	5,325	49,752	11,074		1							
1920	434	21,484	26,980		137							
1923	6	470	14,054		17							
1924		1,373	84									
1925	2,361	30,374	117,962		940							
1926	707	2,212	82,002		1,297							
1927	453	184	1,470		192							
Suspiro, Cape:												
1927	180	377	3,912		462							
Tenass Pass:												
1926	1	3,547	81		3							
Tokeen Bay:												
1904	1,929				5,073							
1905	275				1,967							
1906	500		45,000									
1907	1,675	386	221,125		2,520							
1908	477	149	128,585		6,118							
1909	3,840		187,632		5,346							
1910	771	1,473	26,673		6,422							
1911		3	4,204		5,276							
1912	575	404	3,221		139							
1913	1,644	5,201	48,796		16							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Tokeen Bay—Continued												
1914	440	1,881	3,722		446							
1915	837	2,205	45,080		1,448							
1916	8	790	1,895		929							
1917	126	93	44									
1918	498	27	1,151									
1919	377	3,817	8,082		19							
1920	276	8,457	2,930		8							
1922	5	770	5,718		1,531							
1923	21	68	1,896		414							
1924	715	33,040	35,416		1,808							
1925	816	43,549	222,727		1,779							
1926	1,339	29,917	53,561		2,993							
1927	136	7,384	4,273		1,379							
Tonowek Bay:												
1908		4,488	10,990									
1912					10,888							
1913	6	63	1,550									
1914		2,108	3,526		2,264							
1915		1,169	16,275		239							
1916	92	1,089	2,384		450							
1919	1,794	1,084	24,157		737							
1922	3,624	53,002	205,465									
1923	768	11,538	50,000		690							
1924	1,115	45,496	38,714		2,062							
1925		10,349	25,216		500							
Tonowek Narrows:												
1926	174		3,932		71							
1927	51	171	946		63							
Tranquil Point:												
1924	2,914	6,271	123,860		2,337							
1925	789	5,606	117,235		3,468							
1927	243	429	612		239							
Trocadero Bay:												
1904	2,519											
1905	3,631											
1906	1,480		210,527									
1907	176	49,163	142,905		9							
1909	8		19,101									
1910	954	200	14,000									
1912	18,084	66,909	412,702	754	8,355							
1913	4,459	24,181	557,444	43	3,807							
1914	6,063	58,178	61,429	1,053	3,500							
1915	925	135,442	42,623		41							
1916	813	68,023	13,886	940	3							
1917	1,400	44,417	106,118									
1918	2,514	20,391	32,997		516							
1919	3,484	51,260	110,458		156							
1920	1,042	25,450	34,710		273							
1921			37,054		9							
1922	449	7,607	55,695		1,044							
1923	7,906	47,139	469,925		5,133							
1924	41	7,993	33,807		58							
1925	5,413	116,899	270,458	880	1,696							
1926	3,858	74,218	296,534		3,702							
1927	1,439	3,085	17,183	8	970							
Turn Point:												
1920	1,946	1,631	56,998	43	2,531							
1923	591	844	29,711		1,239							
Tuxekan Island:												
1919	3,778	1,530	57,817		3,248							
1925	900	9,000	106,712		1,000							
1927	1,943	4,838	29,470	5	1,907							
Tuxekan Passage:												
1906	946											
1910	2	679	10,207		31							
1912	1,047	1,577	23,251	25	666							
1913	910	20,578	198,845	10	1,663							
1914	5,503	11,173	33,283		564							
1915	4,982	13,626	234,090		4,305							
1916	3,918	11,635	23,433	61	3,522							
1918	28	150	112									
1919	211	868	7,674									
1920	2,598	2,389	9,806		31							
1922	145	545	5,419		1,002							
1923	6,330	25,719	291,404		1,815							
1924	2,342	22,906	126,000	164	5,564							
1925	1,005	62,532	186,618		742							
1926	2,779	30,648	228,621		2,642							
1927	22	5,260	2,266		30							
Ulloa Channel:												
1920	3	707	3,388									
1923	535	8,280	123,720		422							
1924		540	1,603									
1926		107	1,689									
1927	926	767	3,082	1	399							

TABLE 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Warmchuck Inlet:												
1904					12,202							
1905	2,539				7,819							
1906	1,555		25,743		12,404							
1907					18,036							
1908					7,968							
1909					14,550							
1910					17,035							
1911					12,325							
1912	3,929	14,643	97,472		5,501							
1913	623	5,585	70,793		1,920							
1914					26							
1917					2,227							
1918					5,100							
1919			426		2,777							
1921			72		1,221							
1922	19	239	3,016		15,249							
1923	774	11,684	5,424		690							
1924	651	3,228	32,753		2,894							
1925	15	4,148	13,259		2,795							
1926	937	2,888	1,965		3,250							
1927	508	859	2,399		1,498							
Waterfall:												
1912	16	102	4,904	250								
1914	100	4,594	564									
1915		5,869	7,946									
1917	655	356	628									
1918			2,156									
1920	264	14,828	17,366		233							
1922	72	3,433	4,580		8							
1923	1	625	15,491		1							
1924		1	4		498							
1926	9	660										
Waterfall Bay:												
1913		170	16,804		2							
1919	367	14,336	33,090		497							
1925	1,088	33,546	4,344		4							
1926	47	4,478	3,682		41							
Whale Head Island:												
1912		35	2,246									
Whalekiller Point:												
1924	487	2,750	25,514		1,331							
1925	632	2,708	37,008		540							
White Cliff:												
1927	1,232	1,517	7,164		1,162							
Unallocated:												
1896	5,272		11,286		125,505							
1897	7,753		92,180		89,329							
1898			4,620		41,788							
1899	50,441		133,252		5,690							
1900	19,284		64,367		60,639							
1901	52,197		275,826		156,126							
1902	12,717		640,807		80,517							
1903	27,617		57,662		101,479							
1904					943							
1905	9,157				1,584							
1906	1,500		180,510									
1907	38,728	58,098	435,033	1,000								
1908	1,705	3,005	41,430									
1909	1,500		67,500	10,350								
1910				1,020								
1911	31,997	1,389	194,408	45,222	460							
1912	48,862	142,557	699,302	84,640	28,024							
1913	18,702	6,405	707,362	121,827	34,336							
1914	14,172	30,732	66,096	9,783	8							
1915	20,790	69,761	332,455	72,420	29,491							
1916	87,627	215,791	231,744	17,692	34,692							
1917	115,568	193,052	1,152,194	55,063	9,927							
1918	89,464	238,823	636,349	32,311	48,461							
1919	121,766	399,571	1,026,496	50,531	43,293							
1920	30,753	356,112	563,793	21,979	77,371							
1921	31	50,210	162,741	32,050	30,318							
1922	55,908	107,140	623,265	19,261	21,616							
1923	28,318	89,608	1,282,530	37,968	43,383							
1924	1,989	38,142	221,868		9,450							
1925	28,916	124,866	532,111	40,564	5,480							
1926	34,327	14,623	5,177	22,352	402							
1927	2,946	12,582	18,752	4,479	1,440							
Total:												
1886					5,424							
1887					47,656							
1888	14,528				69,436							
1899			92,094		30,916							
1890	15,331				65,956							

Table 21.—*Salmon caught and fishing appliances used in the west coast of Prince of Wales Island district, 1886 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Total—Continued												
1891	9,033				93,129							
1892	4,700				64,579							
1893					42,963							
1894					47,400							
1895	3,830				52,162							
1896	17,582		11,286		183,157							
1897	15,960		92,180		123,760							
1898	22,087		69,620		103,643							
1899	62,441		186,252		116,690							
1900	31,784		264,367		117,660							
1901	65,197		275,826		167,126							
1902	12,717		640,807		93,017							
1903	45,203		146,662		109,579							
1904	57,073		138,860		157,601	1		19				
1905	51,666		177,506		94,492	21		2		1		
1906	20,176		816,710		87,787	13		2		2		
1907	44,737	115,073	1,276,004	1,000	95,844	18	3,020	5	630	2	110	
1908	36,733	34,166	1,188,613	9,200	83,304	17	2,795	4	720	3	185	
1909	25,148	5,904	1,128,819	10,350	86,062	18	2,950	4	700	2	300	
1910	19,565	111,932	769,349	18,050	92,329	20	3,350	1	293			
1911	81,867	41,972	1,993,339	45,222	145,613	11	1,650	11	2,115	5	250	
1912	115,819	364,812	1,621,614	109,685	133,040	32	5,330	20	3,692	12	1,320	11
1913	60,544	212,673	2,596,303	156,973	64,132	23	3,840	24	3,885	11	775	8
1914	60,635	350,217	615,402	115,406	41,848	23	3,860	16	2,660			4
1915	34,711	460,292	1,475,264	101,410	68,567	19	2,700	36	5,603	8	575	4
1916	159,594	460,869	511,792	22,497	70,178			34	4,700	8	950	4
1917	204,509	414,197	2,228,607	88,243	66,856	13	2,030	42	6,345	12	1,025	12
1918	167,490	334,377	1,241,460	49,652	109,158	22	3,165	37	6,200	8	650	17
1919	187,948	872,536	2,351,619	72,727	144,828	17	2,350	55	10,330	9	1,000	12
1920	53,680	711,299	1,095,091	23,814	132,989	13	1,385	49	8,093	9	955	9
1921	1,013	60,432	403,423	37,750	80,896	10	1,615	9	1,450	8	800	12
1922	101,095	514,194	2,123,150	36,985	111,974			60	9,345			19
1923	79,177	291,801	3,602,621	54,202	99,787	2	130	58	9,020	3	180	22
1924	45,924	465,640	2,181,431	20,895	107,669			73	11,126			22
1925	86,751	1,164,392	3,530,504	77,588	66,250			65	10,620			34
1926	93,474	517,490	2,931,112	39,215	58,869			66	10,950			47
1927	55,766	123,528	282,323	15,200	51,048			54	8,878			60
By lines (included in above):												
1907				1,000								
1908				9,200								
1909				10,350								
1910				18,050								
1911	31,092			45,222								
1912	17,027			108,640								
1913	21,919			146,615								
1914	18,948			115,306								
1915	41,728			101,184								
1916	83,168			21,548								
1917	140,451			84,717								
1918	90,880			49,019								
1919	109,304			72,861								
1920	8,180			23,670								
1921				37,750								
1922	40,878			36,890								
1923	20,488			52,900								
1924	9,162			20,178								
1925	33,077			75,773								
1926	34,877			34,392								
1927	18,016			14,646								

Note.—No catches were reported in the years omitted from each division of this table.

In preparing this table it was necessary to make more or less arbitrary divisions of catches which had been reported under the following designations: "Chatham Strait and west coast of Prince of Wales Island" in 1919; "Chatham Strait, Rocky Bay, and Karheen" in 1923; "Chatham, Peril, and Icy Straits and Bays, and Karheen" in 1921 and 1922; "Icy and Chatham Straits and west coast of Prince of Wales Island" in 1921; "Klawak, Port Santa Cruz, Cape Felix, and Hetta Inlet" in 1912; "Klawak, Sukkwan, Soda Bay, and Sarkar Cove" in 1912; "Klawak, Sukkwan, Soda Bay, and Hetta Inlet" in 1912; "Klawak to Hetta" in 1914; "Cape Ommaney and west coast of Prince of Wales Island" in 1913; "Union Bay, Cape Ommaney, and west coast of Prince of Wales Island" in 1913; "Warmchuck, Hetta, and Klawak" in 1914; "West

coast of Baranof Island, Prince of Wales Island, Tyee, and Chatham Strait" in 1913; "Cape Ommaney and Forrester Island" in 1917; and "Clarence and Sumner Straits, Revillagigedo Channel, and Pacific Ocean" in 1923. These catches were composed of salmon from two or more districts and involved rather large totals, so that it seemed better to divide them in accordance with known facts concerning the field of operations of each company so reporting than to group them as unallocated catches in the whole of southeastern Alaska. In several cases catches from two or more localities within the district were combined by the packing companies; all such data were used without change by including them in the unallocated catch section of the table, as in this way the district receives full credit for the salmon it produced although catches of the individual localities are thereby reduced. These inseparable combinations were reported as follows: "Davidson Inlet, Gulf of Esquibel, and Sea Otter Sound" in 1912; "Forrester, Noyes and San Pedro Islands" in 1913; "Forrester and Noyes Islands" in 1915–17; "Karheen and Warmchuck" in 1914; "Noyes and San Pedro Islands" in 1913, and "Sea Otter Sound, Trocadero Bay, and Pacific Ocean" in 1912.

The table shows the catches at 115 known localities, many of which are of comparatively recent development while others were among the first to be fished. In several cases the data are fragmentary, representing catches in 1 or 2 years only or in rather widely separated years. The table, therefore, presents all the known facts in respect of these places. Some of them were trap locations and others were trolling grounds. The scattered catches in such places may have little significance, but are presented for the sake of completeness and in view of their possible later significance.

Among the more productive localities where fishing has been maintained through a long period of years, Klawak Inlet stands out as the most interesting in the entire district on account of the fact that it has been fished longest and has shown the greatest yield. Unfortunately the complete history of this fishery cannot be given, as no catch statistics are available before 1886 and none in the three years from 1901 to 1903. It is known that a saltery was operated at Klawak for several years before the cannery was opened in 1878 and that for nearly 2 decades the catch consisted largely of red salmon, as no other species appears to have been recorded from this stream until 1898, except 92,094 pinks in 1889 and 2,667 cohos in 1896. These species were undoubtedly always obtainable here, but no commercial use was made of them by the cannery at that time. The Klawak stream was never regarded as a large producer of red salmon, but it maintained for many years a fairly constant catch in spite of the rather intensive fishing that had centered there.

A pink salmon fishery of considerable importance was developed at Klawak after 1898 and the catch of cohos and chums also reached fairly high levels. King salmon were reported first in 1908, when 9,200 were alleged to have been taken. Large catches of kings were also recorded in 1918, 1921, and 1925; none of these was made at the creek, but came from outside waters and were delivered at Klawak for mild curing. The other catches of kings were probably taken in traps along the shore between Craig and Klawak Island. The stream has no king salmon run, though stragglers are occasionally found among the other schools of salmon. The catch of salmon in Klawak Inlet is shown graphically in figure 36.

The catch of red salmon shows the first marked decline in 1925, when it dropped about 40 percent below the catch of the preceding season. A further decrease occurred in 1926, bringing the catch down to 10,734, and in 1927 the catch was 10,012, the lowest figure it had reached since 1886. While positive proof is lacking, it is probable

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that these diminished catches were due at least in part to the seasonal closing and limitation of gear noted above, for it was reported that the escapement of salmon was large in all streams of the west coast of Prince of Wales Island in 1927. The runs of pinks and chums were good in 1926, large catches coming from Klawak Inlet, but there was apparently an almost total failure of these fisheries a year later. The catch of both species had fluctuated considerably over a long period, yet never in the history of Klawak had the catch of pinks been so low, while that of chums had dropped to a lower level but once since 1909.

In view of its long record of 41 years as a producer of salmon, Sarkar Cove merits more than passing notice. The first recorded catch was made here in 1887 and consisted entirely of red salmon, and, with one exception (1905), it produced only

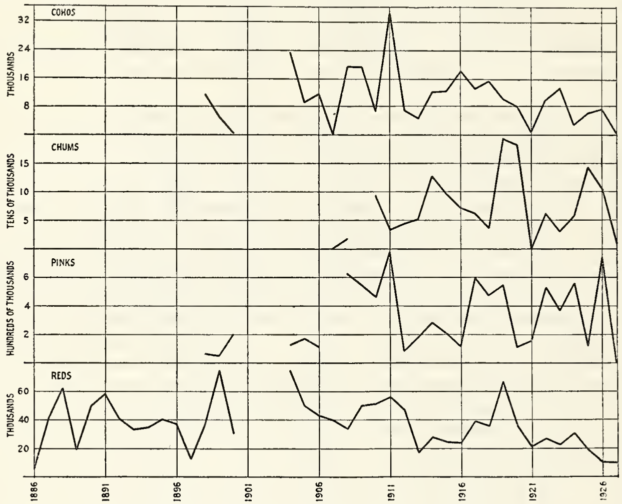

FIGURE 36.—Catch of salmon in Klawak Inlet, 1886 to 1927.

reds and cohos for 23 years. During this period, fishing was carried on near the mouth of the stream or directly in the stream, and at one time a trap was driven across the creek and probably maintained for several seasons, supposedly closing the stream completely to the ascent of salmon. To what extent such fishing prevented the escapement of salmon to the spawning grounds up stream is not known, but it would certainly greatly reduce the number. It is surprising, then, that under these conditions the run was not totally destroyed, and yet there was no marked evidence of depletion until 1913. In 1916 the catch dropped to 110 red and 1 king salmon. During the next 6 years considerably better catches were made, but again in 1923, the run was almost a total failure. The fishery had evidently reached a precarious condition and it was necessary, therefore, in the interest of conservation, to prohibit all commercial fishing in the cove for an indefinite period. That action was taken in 1925.

The unallocated catches of all species in this district are unavoidably large, due to the failure of those engaged in fishing to make correct allocations. It was an easy matter to cover all localities by the simple statement that the fish came from the west coast of Prince of Wales Island, leaving the data thus supplied without value in showing the condition of a fishery at any particular place. On account of this grouping of catches, probably no locality shows a complete record of the salmon it produced. In almost every case gaps occur which cannot now be filled. It was also necessary to include in these unallocated figures catches reported from 42 unknown localities, such as "Nuckleen", "Nuckwell Bay", "Orr Inlet", "Scheley Bay", "Silber Bay", "Sierra Harbor", "Silvers Island", "Snail Bay", "Soucha Bay", and the like. Discussion of the data must obviously be confined largely to the total catch of the district.

Salmon approach the streams of this coast through Davidson Inlet, the channels connecting the Gulf of Esquibel and the ocean, Bucareli Bay, and Meares Passage. Some may come south through El Capitan Passage, while yet others may enter through Tlevak Narrows at the southern end of the district, but it is doubtful if any considerable number use these entrances, else there would have developed a greater concentration of fishing effort at those places. Salmon using the northern gateway probably disperse to the streams of Sea Otter Sound, Tuxekan, and El Capitan Passage; those entering through the other gateways seem to converge and move into Klawak and Shinaku Inlets, although a considerable body diverges into Trocadero Bay. Fishing along the shores of the islands lying between these localities and the ocean takes the first toll from these runs and serves to emphasize the outstanding position of these few localities in the production of salmon in this district.

The final section of the table gives by years the number of coho and king salmon which were caught by trollers operating in this district, although these catches had already been included in other sections of the table. The object of this separation was to give an approximation, at least, of the importance of line fishing.

Figure 37 shows graphically the catch of salmon by species in the entire district. The pink salmon catches showed in general an upward trend from 1900 to the last year herein considered, 1927. They developed with special rapidity between 1905 and 1913 corresponding to the influx of more fishing appliances and the opening of new canneries. Then followed a period of 3 years in which catches were considerably lower, but since that time the trend has been noticeably upward with the exception of the small catch of 1921, when the fishing effort was much reduced, and the exceptionally poor run of 1927, when the catch reached the lowest point since 1905. A material increase in the number of traps could not provide a normal catch; the shortage undoubtedly was due to an actual scarcity of salmon, and since the streams were low, concern was felt for the runs 2 years later. The seriousness of the situation being recognized, all waters of the district were closed on August 18, 4 days earlier than the date fixed in the original order, and the open season from September 14 to October 15 was eliminated, making possible the escapement of such runs as might subsequently appear.

The chum salmon fishery is of more recent development. Once begun, the catches increased rapidly and quite regularly until the suspension of fishing in 1921, which was brought about by the collapse of the market for the cheaper grades of salmon. With the resumption of fishing in 1922, the catch improved, and 3 years later reached a peak far above any previous high level, only to fall with alarming

abruptness in 1926 and 1927, due in part to the shortening of the fishing season and in part to a real scarcity of fish.

Exploitation of the runs of coho salmon began in 1888, but only moderate catches were made previous to 1898, in which year the first substantial improvement was noted. For several years the catch fluctuated between 12,000 and 65,000, but with an increase in the number of trollers and the discovery of good fishing grounds around Forrester and Noyes Islands larger catches resulted consistently, and in 4 years, 1916 to 1919, all previous records for high production were broken. The slump in 1920 and 1921 doubtless was due to economic causes and to the low prices then offered

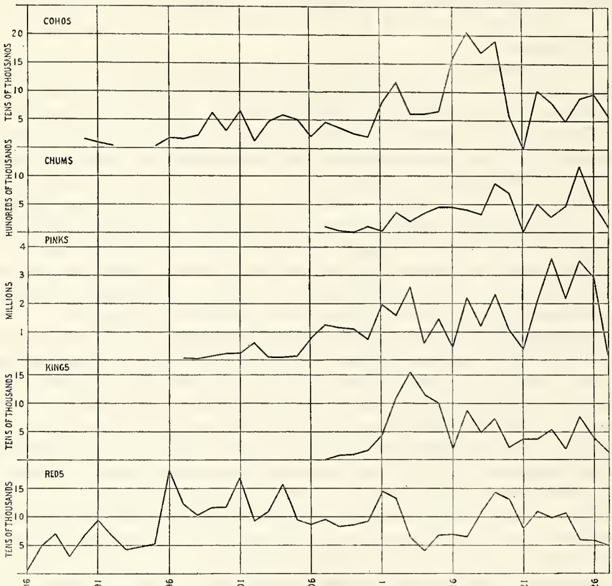

FIGURE 37.—Catch of salmon in the west coast of Prince of Wales Island district, 1886 to 1927.

for fresh fish rather than to a decreased supply of cohos. During these years of extraordinarily heavy yields, the bulk of the catches were made by trollers whose operations were exempt from the seasonal limitations applicable to all other methods of fishing. If the market for fresh fish had not suffered the same demoralization that affected the market for canned salmon there is little doubt that the trollers would have conducted their fishing as usual and that results would have been equally good. During the period 1922 to 1927 the catches of cohos have been fair, but not equal to those of the period just preceding 1921.

In large measure the same situation existed in respect of the king-salmon fishery. Large catches were made from 1912 to 1915, but in subsequent years the trend fell

rapidly until 1927, which was marked by the smallest catch that had been made since 1909. The king-salmon fishery extends quite generally over the district, but the nearby ocean waters between Iphigenia Bay and Dixon Entrance have been the most productive fields. It is conducted primarily by trolling, delivery of catches being made to buyers for the fresh-fish dealers and the cold-storage companies. Statistical reports are not made by the fishermen, but come from the dealers, who frequently are unable to give exact information as to the localities in which the fish were caught. They know in a general way that the catches were made on the west coast of Prince of Wales Island, and that fish from Sumner and Chatham Straits and the west coast of Baranof Island are sometimes included. It is also known that the king salmon of these coastal waters are not all destined to the streams of Alaska, and probably none to the streams of this district, but are members of several populations, probably representing runs to the rivers of the mainland from the Columbia River northward. This wide dispersion of king salmon from these localities was shown by an experiment in 1927 when 382 troll-caught kings were tagged and released off the west coast of Baranof Island. Of the 38 recaptured, 22 were taken at the Columbia River, approximately 1,000 miles south of the point where they were first taken.[10] It is evident therefore that the trollers are making their catches from schools of salmon which are feeding along the coast of the archipelago of southeastern Alaska, and that the effect of their operations upon the runs to rivers in Alaska is not determinable from the statistical data here considered.

The catch of red salmon reached its highest level in 1896, coincident with the opening of a cannery at Hunter Bay in an adjoining southerly district. Since that year there have been 4 fairly good seasons at irregular intervals but with decreasing catches. The poorest catch occurred in 1914. It reached a lower point than had been touched since 1889, but the larger catches in later years have not changed the general trend of the fishery. From 1919 to 1927 the catches have become steadily poorer, indicating continued depletion. Measures have been applied to protect the runs, but insufficient time has elapsed since they were adopted to prove their efficacy.

CORDOVA BAY DISTRICT

The Cordova Bay district covers the waters of the west coast of Prince of Wales Island and the east coast of Dall Island from Tlevak Narrows southward to a line from Cape Muzon to Surf Point. Many small bays indent the shores of these islands and also the shores of the smaller islands lying between them. Figure 38 is a map of this district.

The islands are mountainous and heavily wooded with spruce and hemlock; the streams are small, probably none being more than 6 miles in length, and many have their source in small lakes, especially on Prince of Wales Island.

This region produces all species of salmon in considerable numbers, except kings, and catches have been fairly well sustained through more than 30 years. The early history of its fisheries was never recorded beyond the data arranged by Moser, who reported in 1898 that salmon were taken from these waters for the cannery at Klawak

[10] No account of these tagging experiments has yet been published, but similar experiments were carried on by Canadian authorities off the coast of British Columbia and gave very much the same results. The following reports on these experiments have been published: (1) Pacific Salmon Migration: Report on the tagging operations in 1925. By H. Chas. Williamson. Contributions to Canadian Biology and Fisheries, N.S. III, no. 9, 1927. Toronto. (2) Ibid: Report on the tagging operations in 1926, with additional returns from the operations of 1925. By H. Chas. Williamson. Cont. Can. Biol. and Fish., N.S. IV, no. 29, 1929. Toronto. (3) Ibid: The tagging operations at Quatsino and Kyuquot in 1927, with additional returns from the operations of 1925 and 1926. By H. Chas. Williamson. Bull. Biol. Bd. Canada, no. 26, 1932. Ottawa.

and that a saltery was operated at Hunter Bay prior to the establishment of a cannery at that place. This cannery was built in 1896, which year marks the beginning of the exploitation of runs of salmon, chiefly reds, in many localities of the Cordova Bay district that had not heretofore been fished, although the stream at Hetta Inlet had been fished regularly by the Klawak cannery for 10 years preceding this later development. Salteries were opened at Nutkwa Inlet and at Sukkwan in 1896, at Kasook Inlet in 1897, and at Copper Harbor in 1899, all of which appear to have ceased operat-

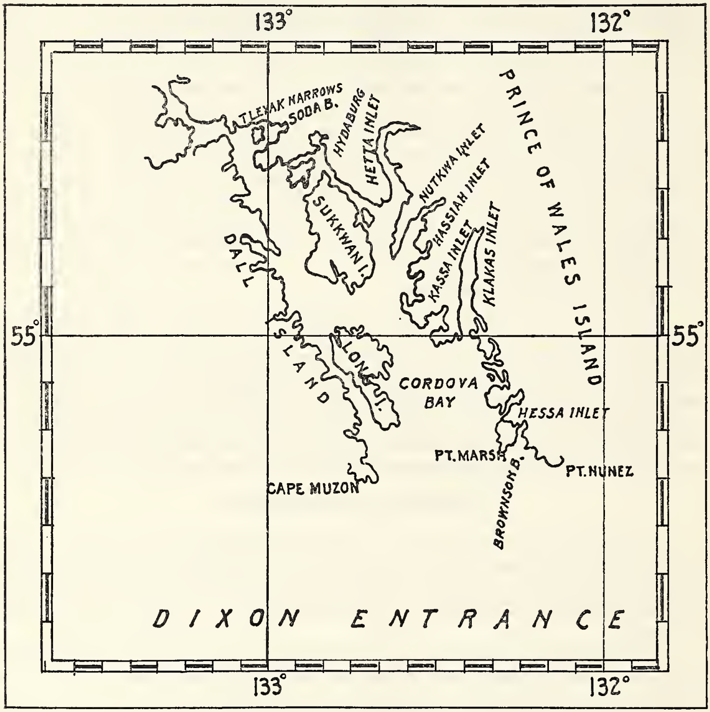

FIGURE 38.—Map of the Cordova Bay district.

ing before 1907. The Hunter Bay cannery was closed in 1904, 1905, and 1906, and occasionally in subsequent years. No increase in the number of packing plants or in the utilization of salmon occurred until 1912, when a cannery was built at Rose Inlet. The opening of this cannery resulted in the development of several new localities and a considerably larger catch of pink salmon than had ever before been made here. In 1921, the year of greatest depression the salmon canning industry has ever known, the plants at Hunter Bay and Rose Inlet were not opened, but a small new plant was

built and operated at Copper Harbor. No additional canneries have since been built in this district.

Evidence of intensive fishing, except possibly at Hetta Inlet and a few other red-salmon streams in that general vicinity, was not apparent before the opening of the Rose Inlet cannery in 1912. In 1911 no traps were operated and only 8 purse seines; but in 1912, 3 traps were driven and 33 purse seines were used, thus showing the first important increase in the intensity of fishing. During the next 10 years the number of traps fluctuated from 1 to 6, the number of seines from 21 to 46, and gill nets from 0 to 15. The last important change began in 1923, with the number of traps increasing to 8 and purse seines to 50, while gill nets dropped to 5. This change continued through 1927, the end of the period here reviewed. In 1924 traps numbered 14, seines 40, and gill nets 6; the number in 1925 was 18, 42, and 7, respectively, showing an increase in all kinds of fishing appliances; in 1926 there were 23 traps and 50 seines and no gill nets; in 1927 traps increased to 36 and seines dropped to 26. Thus in 25 years the character of fishing in this district changed from an almost exclusive use of seines to a preponderant use of traps, the last 4 years witnessing a progressive increase in the number of traps.

Fishing in this district has been limited by the same general regulations as to seasons, gear, and distance interval between traps that were effective in the west coast of Prince of Wales Island district, description of which was given in detail in that section of this review and need not be repeated here. In addition, specific regulations in 1925 and subsequent years closed Hetta Inlet north of the latitude of Eek Point; Kasook Inlet was also closed for 1 mile from the head of the inlet, and North Bay within 1,000 yards of all streams. In 1927 Nutkwa Lagoon was also closed. The closing of Hetta Inlet put an end to fishing at Hetta, Copper Harbor, Portage Bay, Sulzer, Deer Bay, and Eek Inlet, which together constitute one of the most productive fields in this section.

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Alder Grove:												
1921	10	45	1,865		8							
1922	189	911	65,866		847							
1923	165	168	114,286		713							
1924	2,207	1,551	28,062		812							
1925	249	1,170	26,888		198							
1926	768	1,267	19,166		557							
American Bay:												
1922	2,271	4,476	14,525		76							
Baldy Bay:												
1910			2,513									
1911	405	1,025	18,932									
1913	140	809	7,524									
1924	16	740	4,545		2							
1925	123	3,467	5,412		2							
1926	6	1,402	7,469		20							
1927	70	168	367		174							
Blanket Island:												
1907	347		5,169		9							
1908			2,279		96							
1909	15		13,731		71							
1910	86		15,076		203							
1912		4,262	25,175									
1919		240	3,965		7							
1923	61	163	11,866									
1925	138	2,663	6,927		168							
1927		131	2		3							
Breezy Bay:												
1914	151	3,958	777		10							
1920	7	1,805										

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Breezy Bay—Continued												
1923	145	2,503	15,861		30							
1924	22	330	6,707		7							
1925		1,798	30		1							
Brownson Bay:												
1911			80		707							
1918	1		20		731							
1924	38		3,009		102							
1925	41	23	16		30							
1926	10	1	954		604							
1927	741	2,501	15,678		3,605							
Canoe Pass:												
1908	68											
1909			8,000									
1912		14	9,430									
1913	1	987	3,420		1							
1923	10	38	8,660		148							
Coco Harbor:												
1907		200	3,000									
1908		1,053	24,567									
1910			6,440									
1911			7,408		6							
1912	204	2,254	148		2							
1916	5	157										
1918	62	2,319	33									
1919	144	1,144	375									
1923	486	10,931	106,734		108							
1924		29	1,772		34							
1925	236	55,711	39,691		38							
1926	332	30,823	40,507		97							
1927	76	163	792		63							
Copper Harbor:												
1900	2,000				6,000							
1901	7,500				5,000							
1902	1,000				600							
1907	4	64	9,947		29							
1908	278	1,731	30,848		341							
1909	239	691	40,605		16							
1910			13,904		156							
1911			76,638		3							
1912			13,884									
1913		28	7,358		68							
1916	153	307	1,585	2	1,018							
1919	38	1,077	5,597		360							
Datzkoo Harbor:												
1907		300	8,000									
1924	19	222	4,002		20							
1925		433	57									
1926		14	931									
Deer Bay:												
1907	701	2,756	148,824		109							
1908	317	10,492	109,313		642							
1909	542	451	67,753		15							
1910	72	921	46,369									
1911			96,205		558							
1912	629	11,858	60,882		39							
1913	157	650	8,414		7							
1914	24	1,265	2,009									
1915	34	1,075	6,407		23							
1916	7	2,181	1,537		8							
1918	27	160	44									
1919	12	3,394	16,399		33							
1923	9	119	3,821		5							
Dunbar Inlet:												
1907	200	400	3,000									
1910	46		23,558									
1914	1		1,798		3							
1916	264	2,796			4							
1919	99	1,933	37,857		17							
1923	24	367	9,786									
1924		2	2,595									
1925	5	7,096	10,318		1							
1926	176	3,546	7,983									
1927	6	125	434									
Eek Inlet:												
1896					8,688							
1897	473		25,400		9,213							
1908		372	11,989		4,413							
1909		220	21,969		4,752							
1910	490	20	20,601		6,684							
1911	67	31	18,689		3,917							
1912	1,500	407	62,177		6,917							
1914		422	4		903							
1915	4	300	1,635		70							

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Eek Inlet—Continued												
1916	692	3,127	6,476	36	2,656							
1918	257				2,009							
1919		50	430		3,000							
1923	75	1,863	3,766		2							
Eek Point:												
1916	2	2			1,068							
1918	311	185	481		2,550							
1919	7	227	13,039		69							
1922	495	2,236	112,840		2,703							
1923	42	282	98,177		608							
1924	792	2,184	39,852		994							
1926	17	386	2,607		87							
1927	405	450	6,249		641							
Grace Harbor:												
1907	400	1,000	10,009	64								
1909	150	200	9,500	75								
1910			17,333									
1911	1		15,130		44							
1916	150	71	355		4							
1923	4	4,181	2,976									
1924	3	531	1,370		1							
1925		8	532									
1926	202	11,872	11,464		28							
Halibut Nose:												
1919	4	44	1,418		5							
1922	71	616	1,680		9							
1923	34	818	4,897		1							
1924	1,546	4,312	30,296		1,813							
1925	1,214	10,250	36,507		316							
1927	9	9	172		3							
Hassiah Inlet:												
1907	1,220	1,900	22,166		1,803							
1908	191	1,793										
1909	984	1,452	22,776		25							
1910	53		11,573		230							
1914	196	16,217	24,004		2,484							
1915					2,065							
1916	13	2,448			1							
1925	40	82	168		822							
1926	22	17	535		76							
1927	1	4	6		148							
Hessa Inlet:												
1904					4,000							
1905					4,230							
1908	2,654	657	21,414		2,511							
1909	423		10,405		1,590							
1910	709		14,959		1,257							
1911	1,676	8	74,029		3,953							
1912	910	5,716	48,691		1,104							
1913			20,000		100							
1915	520	1,203	12,456		403							
1916	1,460	1,106	10,080		1,104							
1917	504	1,394	17,587		1,761							
1918	1,473	4,712	7,924		1,901							
1922	98	1,013	16,070		206							
1924	495	1,677	12,509		434							
1925	390	10,577	42,105		3,035							
1926	335	4,101	10,624		334							
Hetta Inlet:												
1887					24,022							
1888					47,468							
1889					48,585							
1890					59,673							
1891					1,089							
1892					51,479							
1893					10,586							
1894					47,769							
1895					78,464							
1896					201,299							
1897	12,964		28,196		199,776							
1898	290		25,000		179,109							
1899	539		229,556		250,834							
1900			58,216		138,733							
1904	2,201				51,654							
1905	1,437				53,045							
1906			10,826		42,741							
1907	1,311	1,254	50,419		18,616							
1908	364	3,631	66,511		37,315							
1909	1,440	672	59,996		54,270							
1910	165	2,977	50,744		28,365							
1911	2,007	4,002	86,305		51,747							
1912	7,264	29,433	242,506		61,139							
1913	554	3,425	235,518		48,600							
1914	1,526	43,030	52,687		66,277							

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Hetta Inlet—Continued												
1915	959	22,403	196,608		61,371							
1916	741	26,935	31,993	7	11,297							
1917	2,161	59,375	112,875	35	32,691							
1918	1,868	10,052	12,977		26,008							
1919	339	9,152	38,028		34,188							
1920	511	9,815	13,977	1	37,485							
1921	687	350	48,471		13,801							
1922	101	1,818	83,784		18,938							
1923	165	3,552	194,059		19,770							
1924	80	7,102	32,607		2,101							
High Point:												
1925	25	13,680	5,243		8							
1926	9	593	1,098		5							
1927	477	489	5,597		882							
Howkan Narrows:												
1912	2,808		88,647									
1913			7,311									
1914	475	5,006	18,759		224							
1915	818	5,277	42,402									
1919	1,367	18,451	116,018		977							
1923	247	1,401	22,352		56							
1924	126	291	7,618		116							
1925		2,236	31									
Hunter Bay:												
1896	13,481		85,782		7,618							
1897			44,501		3,848							
1904			100,000		21,000							
1905	4,292				43,933							
1906					14,372							
1907	1,270	586	15,662		13,006							
1908	3,265	323	73,288		7,298							
1909	894	322	50,983		4,254							
1910	5,419	363	34,624		10,608							
1911	2,371	18	173,506		11,681							
1912	3,485	2,344	126,331		8,797							
1913		288	218,617		2,103							
1914	394	3,890	17,516		752							
1915	157	291	12,737		7,077							
1916	5,428	6,201	112,575		7,913							
1917	676	917	14,792	1	5,953							
1918	1,489	637	75,303		9,553							
1919	2,736	4,528	198,785		7,800							
1920	1,175	30,269	90,445		5,695							
1921			26,395		8,369							
1922	4,057	13,217	230,846		11,224							
1923	2,076	4,393	97,878		4,010							
1924	2,607	4,816	52,461		6,760							
1925	146	1,287	9,146		2,149							
1926	767	1,105	45,908		2,439							
1927	176	23	325		1,269							
Hydaburg Bay:												
1912	1,230	6,157	45,032		897							
1913	854	12,914	36,662		25							
1914	5,152	27,727	13,686		1,423							
1915	1,447	48,136	69,916		236							
1916	4,477	29,271	8,417		291							
1917	2,659	30,918	92,015		180							
1918	946	1,659	774									
1919	19,128	148,884	80,789		3,144							
1920	123	23,807	3,618		524							
1921			28,807		48							
1922	3,737	20,336	131,959		373							
1923	6,285	99,298	1,177,904		6,748							
1924	544	13,385	12,042		68							
1925	4,795	71,227	80,385		8,279							
1926	4,849	13,812	33,644		290							
Jackson Island:												
1912	51	1,838	3,722									
1913		218	7,106									
1918	8		1									
1919	8	353	4,327		778							
1923	12	367	9,609		9							
1925	416	10,717	1,749		48							
1926	3	16	3,066		7							
Kaigani Point:												
1923	719	462	118,047		775							
1924	936	3,572	56,482		1,227							
1926	1,632	2,882	34,502		927							
Kaigani Strait:												
1912	3,000	13,930	200,000		1,152							
1913			210,000		570							
1914	1,162											
1915					611							

Table 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Kaigani Strait—Continued												
1917	1,825	9,313	187,127		25							
1919	6	252	3,327		18							
1925	220	1,421	12,038		117							
1926	603	2,423	19,606		344							
1927	1,808	1,367	15,068		2,644							
Kasook Inlet:												
1888					1,829							
1896					1,340							
1897			20,456		2,415							
1908					831							
1910	241	435	4,938		244							
1911	88		9,614		1,307							
1912					3,000							
1914	7				110							
1918	1,158		38									
1919	7	2,256	12,826		67							
1922	237	5,178	36,348		756							
1923	144	1,074	35,358		1,031							
1925	301	5,462	37,427		1,347							
1926		120	1,233		139							
1927	521	508	14,628		1,214							
Kassa Inlet:												
1912			4,964									
1913		114	36,956		511							
1916	8	283	958		51							
1919		248	2,203									
1923	17	267	6,532		479							
1925	1,336	21,565	157,928		3,654							
1926	475	1,950	32,700		550							
1927	560	311	1,641		655							
Keete Inlet:												
1907	1,293	3,649	21,254		199							
1908	204	4,788	34,980		80							
1909	1,135	2,337	88,533		1,072							
1910	385	3,853	60,411		166							
1911	947	8,111	13,841		49							
1912	1,832	25,100	4,461									
1913		6,014	52,913		857							
1914	10	3,331	2,634		30							
1915	248	8,556	11,624		168							
1916	875	12,572	721		57							
1918	1,494	10,019	1,181		91							
1919	242	6,866	6,259		6							
1920		2,364	302									
1922	318	12,699	1,549		164							
1923	1,052	7,255	204,077	7	1,315							
1925	882	25,344	125,114		1,024							
1926	2,781	71,190	92,760		1,571							
1927	370	749	3,998		676							
Klakas Inlet:												
1887					9,330							
1896	2,657		32,469		7,314							
1897			108,031		23,330							
1904					15,000							
1905		750			6,720							
1907	1,190	4,553	77,068		9,507							
1908	848	2,375	114,006		11,559							
1909	1,049	1,860	105,766		4,149							
1910	124	1,402	77,127		3,976							
1911	50	98	100,093		3,291							
1912	1,629	7,110	97,686		2,386							
1913		6,851	61,272		804							
1914	332	31,106	60,097		10,180							
1915	1,105	25,075	109,510		12,327							
1916	1,348	6,805	21,353		4,791							
1917	1,818	13,772	43,237		10,014							
1918	2,237	15,864	11,598		7,732							
1919	871	22,255	152,492		1,824							
1920	839	27,319	18,249		1,026							
1922	584	16,439	61,060		4,679							
1923	967	3,500	154,813		1,111							
1924	707	31,620	69,092		2,490							
1925	1,068	34,419	143,729		2,029							
1926	721	27,597	56,762		2,580							
1927	387	349	1,370		466							
Leading Point:												
1927	109	41	179		111							
Lime Point:												
1910		3,100										
1911		6	24,000		241							
1912			12,228									
1914	59	8,569	26,390		350							

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Lime Point—Continued												
1915	7	395	4,982		109							
1916	2	7	741		31							
1917	468	669	3,345									
1918	164	1,006	5,831		1,269							
1919	14	685	4,267		397							
1922	269	3,558	56,119		2,386							
1923	27	138	33,907		56							
1924	1,584	8,209	161,226		5,162							
1925	1,826	16,338	142,358		2,111							
1926	975	6,918	126,455		2,521							
1927	1,675	2,915	18,457		3,906							
Little Daykoo:												
1907	200	500	5,000									
1909	25	100	2,500									
1916	53	935	1,259		4							
1919	71	59	1,730		196							
Long Island:												
1910	38	15	1,568									
1912		5,000	105,989									
1914	6	3,116	832		4							
1918	314											
1923	248	917	56,178		470							
1924		85	1,844									
1925	43	3,820	16,671									
1926	480	5,809	7,960		6							
1927	353	555	10,908		651							
Mabel Island:												
1926	105	243	4,378		96							
Marsh, Point:												
1927	568	4,038	30,126	18	619							
McFarland Island:												
1926	11	383	4,014		25							
McLeod Bay:												
1923	70	447	29,528		239							
1924	46	4,351	14,825		121							
1926		69	217									
Mellon Rock:												
1924	1,442	4,241	41,965		1,993							
Muzon, Cape:												
1919	3		683		822							
1922	249	2,703	7,250		122							
1924	5,699	10,498	142,168		11,396							
1925	3,888	33,915	251,862		7,519							
1926	4,527	7,597	82,394		2,466							
1927	1,681	1,682	17,401	1	2,590							
North Bay:												
1914	12	1,847	2,567									
1919	4	593	1,524									
North Pass:												
1923	288	6,002	64,782		21							
1926		2,174	128									
1927	248	1,508	530		2							
Nutkwa Inlet:												
1896	9,442		500		850							
1897	8,086											
1904	3,037				11,000							
1907	1,540	774	10,606		24							
1908	3,749	14,673	54,433		962							
1909	452	1,704	94,731		460							
1910	996	1,107	102,697		1,577							
1912	2,633	6,593	35,068		195							
1913		2,580	145,810		1,030							
1914	1,732	20,066	143,324		1,420							
1915	3,857	35,610	220,171		4,301							
1916	4,514	37,820	490,838	1	6,631							
1917	6,552	77,699	234,106		1,687							
1918	3,385	27,603	176,813		7,437							
1919	636	44,209	331,271		11,870							
1920	1,021	96,386	9,731	10	2,169							
1921			2,317		519							
1922	3,655	36,224	648,856		8,481							
1923	4,355	7,207	605,707		9,621							
1924	1,214	23,133	189,693		4,300							
1925	914	25,283	247,812	1	2,111							
1926	2,671	7,894	184,074		7,003							
1927	717	2,367	4,268		1,477							
Palm Bay:												
1924	2	4	1,336		67							
Pond Bay:												
1925		336	665									
Portage Bay:												
1917	202	3,160	690									
1918	1	361	537		42							
1924			15,000									

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Rose Inlet:												
1913	186		6,693		5							
1914	5											
1915			6,168		3							
1917	186	1,118	805		38							
1918				65								
1920	58	991	14,439		314							
1922	107		27,560									
1923	11	320	15,491		12							
1924	1,274	15,515	57,127		176							
1925		108										
1926	7	214	4,088		41							
Ruth Bay:												
1918		205	15									
Saltery Point:												
1927	218	767	3,852		196							
Sawmill Covo:												
1907		100	3,000									
1910	160		10,323									
1914	57	655	939									
1916	56	60			2							
1917	523											
1923	137	460	49,973		86							
1925	116	3,884	13,627									
1926	319	100										
1927	6	5	247									
Seal Bay:												
1907			400									
1924		50	1,660									
Shipwreck Point:												
1926	20	200	400		10							
1927	1,403	1,079	5,670	3	2,047							
Shoe Rock:												
1922	551	2,908	123									
Soda Bay:												
1904	5,594											
1905	1,288											
1906	1,231											
1910	1,000											
1912	380	10,301	20,584		135							
1913	219	386	8,696		14							
1914	2,328	30,105	20,608		50							
1915	1,113	67,725	45,849		107							
1916	1,247	24,455	3,448		189							
1917	1,409	21,342	46,728	4	191							
1918	321	10,071	6,611		2							
1919	3,747	35,567	138,663		311							
1920	33	7,052	2,964		14							
1922	313	2,635	5,509		108							
1923	1,010	5,736	54,805		317							
1924	1,183	37,201	24,833		90							
1925	572	33,141	34,990		44							
1926	2,217	43,742	54,184		521							
1927	419	2,100	1,162		119							
Sukkwan Island:												
1912		5,000	100,000									
1918	993	865	2,600									
1924	1,433	3,225	51,764		960							
1925	1,484	14,444	56,202		924							
1926	1,293	5,070	102,742		1,598							
1927	1,562	2,335	18,642	2	2,645							
Sukkwan Strait:												
1890	4,403											
1896	4,830											
1897	3,924											
1904	14,600											
1905	12,027											
1906	8,819											
1907	5,274	556	7,976		1,242							
1908	3,439	11,052	24,979		22							
1909	2,334	348	40,885									
1910	3,140	1,306	31,217									
1911	2,292	6,329	17,837		247							
1912	1,590	30,785	49,241	317	718							
1913		980	124,186									
1914	4,983	88,140	122,460		324							
1915	1,367	42,766	170,311									
1916	2,041	23,613	6,157		677							
1917	3,457	24,006	35,172		56							
1918 [1]	5,030	10,687	30,763	2,394	1,373							

[1] The catch in this year includes 4,988 cohos and 2,360 kings that were taken by trollers.

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Sukkwan Strait—Continued												
1919	79	12,572	102,462	1	1,114							
1923	25	495	22,118		32							
1924			32,385									
1925	3,963	59,900	141,545		606							
1926	1,576	24,755	20,498		953							
1927	664	1,346	7,775		948							
Sulzer:												
1907	585		5,000									
1908	192	5,663	43,815		21							
1910	30	517	64,338									
1911	104	623	43,211		53							
1912	1,933	13,830	59,292		8							
1915		1,040	10,130									
1916	204	12,591	2,237		14							
1917	181	7,560	4,141		7							
1918	421	309	184		13							
1919	6	2,853	22,750		244							
1920	24	1,952	13,926		26							
1923	23	419	40,820		469							
Tah Bay:												
1908	1,435											
1909	315	146	5,614		19							
1910	228											
1911	193		1,089									
1912			6,859									
1913		989	19,848									
1914	37	551	2,792		56							
1916	662	975	1,307		6							
1918	446	113	263									
1924	334	790	11,017		677							
Tlevak Narrows:												
1906			92,000									
1914		1,823	3,615									
1915		743										
Tlevak Strait:												
1915	2,310	38,561	164,346									
1916		34,169	38,067	9	2,253							
1917	1,160	47,762	42,131		117							
1918	14	16,302	25,856		226							
1922	165	3,426	4,751		768							
1923	2,362	12,485	200,666		496							
1924	813	42,965	52,975		669							
1927	173	450	505		11							
Turn Point:												
1918		1	1,432		107							
1927	461	292	1,315	1	530							
Vesta Bay:												
1925	564	24,152	8,503		4							
1926	5	1,883	6									
View Cove:												
1926		823	5,830		2							
1927	3	292	19									
Webster, Point:												
1912	594	493	34,648	29	928							
1913	761		15,613		489							
1914			559		1							
1922	55	844	19									
1924	2,840	6,938	91,951		4,447							
1925	1,212	11,816	81,320		839							
1926	1,213	3,923	92,917		1,962							
1927	710	752	4,315		1,195							
Unallocated:												
1896	9,168		2,887		39,568							
1897	19,538		99,030		18,316							
1898	62,441		161,252		16,690							
1899	52,155		352,330		28,240							
1900	36,630		889,787		30,198							
1901	26,138		766,400		82,642							
1902	19,000		902,000		150,000							
1903	80,000		522,000		120,000							
1905			160,000									
1908	800	2,500	37,400									
1909	125											
1910	1,304	457	36,754		106							
1911	2	158	16,098		979							
1912	3,850	19,058	54,249	263	734							
1913		264	11,126									
1914	1,557	36,289	89,071									
1915		3,681	4,462									
1916	80	34	2,914		188							
1917	685	20,100	145,453		939							
1918	9,515	44,936	98,603		3,934							

TABLE 22.—*Salmon caught and fishing appliances used in the Cordova Bay district, 1887 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Unallocated—Continued												
1919	10,595	47,637	497,088	------	18,516	------	------	------	------	------	------	------
1920	2,328	151,195	77,685	------	22,244	------	------	------	------	------	------	------
1922	1,867	27,090	15,905	------	12	------	------	------	------	------	------	------
1923	1,160	496	31,570	------	268	------	------	------	------	------	------	------
1924	1,982	5,375	128,466	7	19,777	------	------	------	------	------	------	------
1925	2,166	34,557	40,922	------	766	------	------	------	------	------	------	------
1926	1,881	49,720	171,618	------	1,964	------	------	------	------	------	------	------
1927	1,285	2,392	13,710	------	6,832	------	------	------	------	------	------	------
Total:												
1887	------	------	------	------	33,352	------	------	------	------	------	------	------
1888	------	------	------	------	49,297	------	------	------	------	------	------	------
1889	------	------	------	------	48,585	------	------	------	------	------	------	------
1890	4,403	------	------	------	59,673	------	------	------	------	------	------	------
1891	------	------	------	------	1,089	------	------	------	------	------	------	------
1892	------	------	------	------	51,479	------	------	------	------	------	------	------
1893	------	------	------	------	10,586	------	------	------	------	------	------	------
1894	------	------	------	------	40,769	------	------	------	------	------	------	------
1895	------	------	------	------	78,464	------	------	------	------	------	------	------
1896	39,578	------	121,638	------	266,677	------	------	------	------	------	------	------
1897	44,985	------	325,614	------	256,898	------	------	------	------	------	------	------
1898	62,731	------	186,252	------	195,799	------	------	------	------	------	------	------
1899	52,694	------	581,886	------	279,074	------	------	------	------	------	------	------
1900	38,630	------	948,003	------	174,931	------	------	------	------	------	------	------
1901	33,638	------	766,400	------	87,642	------	------	------	------	------	------	------
1902	20,000	------	902,000	------	156,000	------	------	------	------	------	------	------
1903	80,000	------	522,000	------	120,000	------	------	------	------	------	------	------
1904	25,432	------	100,000	------	102,654	3	------	4	------	------	------	------
1905	19,044	750	160,000	------	107,928	8	------	------	------	------	------	------
1906	10,050	------	102,826	------	57,113	5	------	------	------	------	------	------
1907	15,535	18,592	406,491	64	44,544	2	230	10	1,750	1	100	------
1908	17,804	61,103	649,822	------	66,091	12	2,710	2	400	1	200	1
1909	10,361	11,194	684,352	75	70,709	5	660	8	1,400	------	------	------
1910	14,686	16,473	697,811	------	53,572	2	300	8	2,345	------	------	------
1911	10,203	20,401	792,705	------	78,783	2	300	8	1,320	------	------	------
1912	35,522	201,483	1,511,894	609	88,151	7	1,130	33	6,195	------	------	3
1913	2,872	37,497	1,245,043	------	55,184	2	150	26	4,392	------	------	1
1914	20,206	327,113	607,128	------	84,601	------	------	34	4,430	8	825	1
1915	13,946	302,837	1,089,714	------	88,871	------	------	35	5,750	3	375	2
1916	24,482	228,921	743,018	55	40,258	------	------	32	5,240	15	750	4
1917	24,466	319,105	980,204	40	53,659	------	------	26	4,530	6	1,148	6
1918	31,935	158,066	459,882	2,459	64,978	4	600	32	5,063	13	2,600	5
1919	40,163	365,529	1,794,572	1	85,763	12	900	46	9,160	14	1,400	4
1920	6,119	352,955	245,336	11	69,497	------	------	21	3,665	------	------	2
1921	697	395	107,855	------	22,745	6	910	------	------	8	800	1
1922	19,389	158,327	1,522,619	------	51,852	------	------	35	5,800	5	500	3
1923	22,455	178,124	3,607,004	7	49,006	------	------	50	8,270	5	500	8
1924	29,984	234,944	1,385,256	7	66,816	------	------	40	6,510	6	600	14
1925	28,373	542,330	1,777,918	1	38,190	------	------	42	7,440	7	700	18
1926	31,008	336,634	1,285,422	------	29,823	------	------	50	8,538	------	------	23
1927	17,862	32,263	205,408	25	36,322	------	------	26	4,535	------	------	36

NOTE.—No catch was reported in the years omitted from each division of this table.

The catch of salmon in the Cordova Bay district is shown in table 22, which comprises 65 localities whose identity has been preserved, and one section presenting the unallocated catches of the district which include salmon reported from 28 unidentified localities, such as "Bruce," "Cadez Bay," "Chasqua," "Hassan Bay," "Jim Spoon Place," "Jumbo Creek," "Keith," "Klakas Nephew," "McKau Inlet," "Prince Point," "Puegh Bay," "Point Simmons," "Sixmile Creek," "Spoons Church," and several more equally obscure places. Other combinations of catches were made, as follows: Those at Captain Johns Creek and Captain Johns Bay were added to Dunbar Inlet catches; those at "Cogo" Harbor and "Kakoo" Bay were included with the catches at Coco Harbor; Howkan Island and Howkan Channel catches were combined with Howkan Narrows fish; Dog Salmon Bay catches were included with fish from Hessa Inlet; Kassa Inlet and Hassa Inlet were regarded as the same and the catches are shown under the name of the latter; Daykoo Harbor and Daykoo catches appear under the name of Little Daykoo; "Dutch Kenii Bay" was changed to McLeod Bay;

the catches at Soda Bay and Soda Harbor are given under the name of the latter; and an arbitrary division of the catch reported from "Klawak, Sakar Cove, Tonowek Bay, and Hetta Inlet" in 1912 was divided so that one fourth of the catch was credited to Hetta Inlet.

Almost nothing is known of the movement of salmon into these waters, whether they come from the north through Tlevak Narrows or from the south through Dixon Entrance. If the location of traps in the district can be accepted as a safe criterion, it may be assumed that the largest body of salmon enters from the south and strikes for the streams of Prince of Wales Island. The greater number of traps are located along that shore and at the southern entrance to the straits between the larger islands. If the bulk of the runs came from the north, it is reasonable to assume that fishing would be concentrated at Tlevak Narrows, that more traps would be located in the northern part of Tlevak Strait than 30 miles south of it, and that the

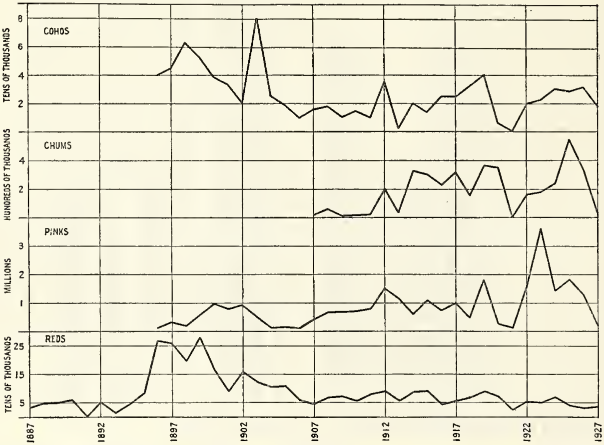

FIGURE 39.—Catch of salmon in the Cordova Bay district, 1887 to 1927.

largest catches would be made in that region. The absence of these is at least negative evidence that the incoming salmon do not enter through Tlevak Narrows in any considerable numbers.

Figure 39 shows graphically the catch of all salmon, except kings, in this district as far as data were available. The curve of production for each species has its own peculiarities. In respect of red salmon, the apparent extraordinary yields in five years (1896 to 1900), may be due in part to faulty data, as it would seem likely that if these large catches were possible when the district was but slightly developed, similar ones would be made again as the fishing effort kept step with the increase in canneries and the greater demand for salmon, considering the undeveloped condition of the district at that time and during the next 10 years. Although there has been no startling change in the trend of the red-salmon catches since more intensive fishing began in 1912, the curve is steadily downward. This species, however, is not an

important element in the fisheries of Cordova Bay. The smaller catches in the last 3 years are accounted for by the prohibition of fishing in Hetta Inlet since 1924, that being the most productive red-salmon locality in the district.

The catch of pink salmon shows a more even trend than that of the other species. In 1923 this district, among others, had a phenomenal run of pinks which made possible the largest catch in its history, being double that of any other year. Four years later it had the poorest run ever known in that section. These extremes seem to be due entirely to biological factors, as no satisfactory explanation of a superabundance of pinks in one year and an abnormal scarcity in another can be found in the economic conditions that might then have affected the industry. The small catches in 1920 and 1921 were due to causes entirely different from those existing in 1927, being in no sense biological upsets but induced largely by an inactive market for pink salmon.

The chum fishery is of comparatively later development than those of the other species and the trend of the catches has been decidedly upward, the high point in 1925 being far above the yield in any previous year. The catch in 1926 was also good, having been exceeded but three times in the history of the fishery. For reasons already assigned, the catch in 1927 was the smallest on record, excepting that of 1921, when little fishing was done.

The catch of cohos shows marked irregularities, the earliest years being the most productive. From 1904 to 1911 this fishery became relatively unimportant, but thereafter rather wide fluctuations in catches occurred. The good years were followed by the precipitous drops of the poor years, and these were succeeded by a gradual improvement in catches. These recurring evidences of strength, weakness, and recovery are interesting peculiarities of this fishery but are probably not indications of depletion.

King salmon are rarely taken in this district. The reported catch of 2,360 in Sukkwan Strait in 1918 is open to question as being an error in allocation. It was made by trollers and was doubtless reported by the purchaser as coming from the point of delivery rather than the fishing grounds.

CLARENCE STRAIT DISTRICT

The Clarence Strait district covers the waters of the east coast of Prince of Wales Island from Point Colpoys on the north to Surf Point on the south, Stikine Strait and Chichagof Pass, the waters of the west coast of Etolin Island and of Cleveland Peninsula, between Lemesurier Point and Caamano Point; the waters of Gravina Island, except Tongass Narrows; the waters of the western and southern shores of Annette Island, between Walden Point and Annette Point, and the waters of Duke Island, west of a line from Cape Northumberland across Felice Strait to Annette Point, and those of all the smaller islands lying within these boundaries. (See fig. 40.) It is a large district, approximately 132 miles in length, and for many years it has been the field of important salmon fisheries and intensive fishing. The labyrinth of bays and the hundreds of streams present ideal conditions for the production of salmon and have made possible an annual commercial catch aggregating millions of fish. Some sections of the shore have no deep and intricate indentations but they form equally important fishing grounds on which yet other millions of salmon have been caught during their migrations.

The development of these fisheries began commercially with the salting of red salmon at Karta Bay before 1888, and at Cholmondeley Sound, Thorne Bay, Tolstoi

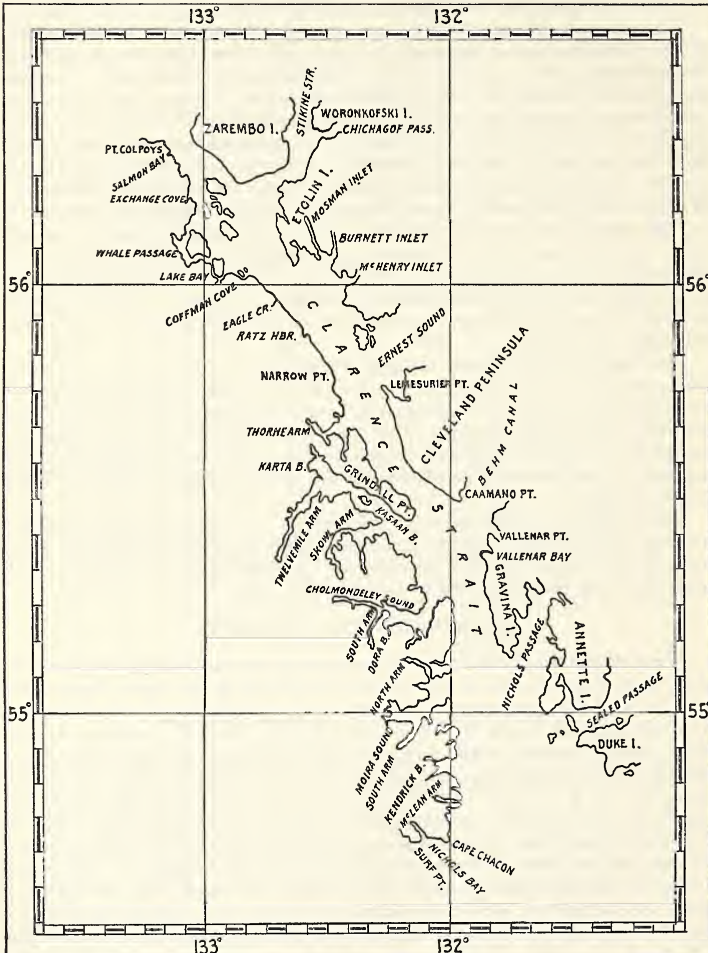

FIGURE 40.—Map of the Clarence Strait district.

Bay, and Moira Sound a few years later. The exact year in which these operations commenced is not known, but in a general way salmon salting antedated salmon canning by several years in these localities. According to Moser, the first salmon for canning were taken at Karta Bay in 1888 and packed at Loring. In time, the salteries were abandoned or gave way to canneries in all of these several localities, except Thorne and Tolstoi Bays. During the intervening years the entire catches went to canneries outside of the Clarence Strait district. The first cannery on Clarence Strait was located at Lake Bay. It was followed by the establishment of canneries on Kasaan Bay, Cholmondeley Sound, Moira Sound, and at Metlakatla, the latter coming as a result of the presidential proclamation in 1896, creating the Annette Island Fishery Reservation for the benefit of the Tsimpsean Indians who, under the leadership of William Duncan, had moved in a body from British Columbia, and the Alaskan natives who might settle on Annette Island. In this period of development, exploitation of the fisheries centered at the streams where red and coho salmon were obtainable, the chronological order of development being as follows: 1888, Karta Bay; 1889, Kasaan Bay, Thorne Bay; 1892, Johnson Cove, Port Johnson, Kegan Cove, Moira Sound, Tamgas Harbor; 1894, Dora Bay; 1896, Lake Bay, Meyers Chuck, Salmon Bay, Whale Passage, Kina Cove, Skowl Arm, and Nichols Bay.

All of these streams except those at Meyers Chuck on Cleveland Peninsula and Tamgas Harbor on Annette Island are located on Prince of Wales Island. In 1900 a floating saltery was operated at Kasaan Bay and prepared chum salmon for Japanese markets.

The growth of the industry, however, was not dependent upon the utilization of red salmon as it was soon discovered that the chief fishery resource of the district consisted of its large supply of pink salmon which were widely distributed in these waters. Utilization of this species was almost contemporaneous with the packing of red salmon and in a few years the production of pinks exceeded the combined pack of all other species. The industry expanded rapidly, new fishing grounds were opened and the fishing effort was constantly increased until Clarence Strait became one of the most highly developed and productive districts in all of Alaska. It was also discovered that salmon enter the strait both from the north and from the south and that the schools followed rather definite routes in their migrations. Runs of large volume struck the western shore of Gravina Island and Cleveland Peninsula, a circumstance that led to intensive trap fishing in those localities. In time, traps fairly lined both sides of Clarence Strait, more especially in the southern part. Purse seines were used in all localities where salmon congregated and trolling was followed in the more open waters of the district. The peak of production was reached in 1923 with a catch of all species of approximately 13,000,000 salmon, which was over one fourth of the total catch in southeastern Alaska that year and approximately one sixth of the entire catch in Alaska. Actually, the relative productivity of this district was somewhat greater than these figures indicate on account of large unallocated catches in 1923, a large proportion of which unquestionably came from this district.

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part:												
Abraham Island:												
1919	4,116	3,451	94,003		8,360							
1920	2,418	4,695	43,788	13	3,418							
1927	154	193	2,943		968							
Barnes, Point:												
1914		14,501	52,549		289							
1923	4,401	1,717	110,624		5,641							
1924	4,229	2,330	45,314	33	11,800							
1925	505	2,056	31,851		513							
1926	1,350	1,015	22,033	3	1,490							
1927	552	633	9,266	37	4,399							
Bonita Passage:												
1919	540	3,621	53,538		1,452							
1920	171	4,654	14,589	1	577							
1925	44	1,330	4,821		102							
1926	86	1,520	10,081		235							
1927	116	1,385	6,451		118							
Burnett Inlet:												
1908			2,560									
1912			72,000									
1914		1,133	1,570		8							
1918				160								
1923		300	10,000									
1924	10	6,500	7,500		40							
1925	334	6,072	59,434		646							
1926	217	3,123	35,005		421							
1927	17	353	580		22							
Coffman Cove:												
1906	1,000	5,000	10,000									
1907	2,000	231	5,000		1,000							
1908	2,000	700	5,000									
1909	69	3,163	9,280									
1910	109	1,123	12,432									
1911	921	1,147	10,118									
1912	242	652	1,669									
1913	1,114	2,072	8,850									
1914			20,661		48							
1915	898	1,271	21,688		354							
1917	19	217	805		1							
1918		2,200										
1919	44	81	147									
1920		347										
1922	189	3,080	15		44							
1924	40	566	1,016		4							
1926	2,248	2,918	26,973	3	4,024							
1927	876	1,174	12,989	68	4,920							
Eagle Creek:												
1904	1,351		51,334	13	15,717							
1905	12,325	28,293	77,146		16,576							
1906	2,254	7,951	98,094	21	16,782							
1907	1,096	2,333	43,441	2	11,809							
1908	46	7,649	3,077		3,949							
1909	68	1,947	38,526		1,678							
1910	2,613	25,823	33,153	14	12,057							
1911	5,340	26,509	142,136	6	7,488							
1912	3,893	27,806	88,117		12,242							
1913		340	4,309		196							
1914		1,073	21,177		2,087							
1915	2,231	22,470	97,018		7,328							
1916	2,043	66,977	78,130		3,445							
1917	5,772	17,253	10,378		4							
1918	5,210	103,392	265,662	6,650	12,395							
1919	14,956	70,418	109,080		21,038							
1920	5,050	59,786	145,103	198	14,688							
1921	4,764	6,466	40,518	19	10,187							
1922	5,607	26,621	228,258	2,913	5,648							
1923	5,987	48,784	328,671	3	13,260							
1924	6,124	13,710	118,840	9	15,779							
1925	3,445	20,201	215,356	190	12,183							
1926	5,100	42,402	203,202	54	22,024							
1927	1,453	2,190	17,267	350	16,086							
Etolin Island:												
1914	1,011	14,409	134,149		720							
1915	118	2,708	62,217		973							
1916	1,504	47,450	186,659		976							
1917	470	158	8,660									
1919	830	70,819	90,608	6	6,977							
1920	386	45,124	26,678	6	1,888							
1923		100	5,000									
1925	2,091	4,517	168,022		6,395							
1926	1,505	1,155	43,397		4,618							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Exchange Cove:												
1908	1,621	5,000	7,588									
1912		3,305	3,770		820							
1913	345	3,891	2,094		133							
1914	258	1,547	3,513		17							
1915	441	1,585	11,693		248							
1916	95	2,076	2,636									
1917	735	6,334	22,964									
1918	47	1,323	8,735									
1919	86	1,146	4,309		100							
1922	589	4,583	27,793		547							
1923	504	579	2,663		38							
1924	444	728	1,721		18							
1925	34	5,015	8,773		197							
1926	421	4,996	20,076		434							
1927	260	329	460		608							
False Island:												
1915	770	408	50,117	3	1,815							
1925	2,442	13,991	150,078	221	5,092							
1926	2,065	9,327	207,317	113	4,181							
1927	1,471	4,170	22,733	180	3,166							
Figgins Point:												
1916	1,885	1,513	30,071	38	1,399							
1926	2,954	9,005	118,008		3,172							
1927	744	644	698	9	1,707							
Harrington Point:												
1920	113	155	124		3							
1926	576	901	22,495		1,795							
1927	432	675	4,622	15	2,658							
Kelp Point:												
1916	830	675	16,136		1,966							
1926	239	844	19,006	2	1,168							
1927	119	404	3,917		210							
Lake Bay:												
1896	58,145											
1897	47,584											
1905	22,000		2,500		3,000							
1906	20,000	1,000	1,000		1,000							
1907	15,000	5,000	5,000		8,000							
1908	17,832	378	6,000		9,259							
1909	4,981	1,125	6,026	5	4,176							
1910	4,228	11,233	718		5,783							
1911	25,882	10,328	117,724		10,043							
1912	29,656	3,509	19,460		1,431							
1913	10,303	10,728	54,218		9,659							
1914	14,562	12,240	15,864		22,432							
1915	23,948	5,143	48,255		18,561							
1916	15,317	9,131	5,552		9,254							
1917	8,779	6,176	40,997		5,060							
1918	4,602				2,099							
1920	2,810	8,731	4,599	35	5,011							
1922	224	55	102		23							
1923	4,012	2,832	8,551		487							
1924	950	2,571	6,586		350							
1926	75	270	807		14							
1927	46	86	205		40							
Lemesurier Point:												
1911	7	1,899	160,368		6,844							
1914	215	8,727	83,564	47	14,022							
1915	3,031	6,379	204,107	323	5,695							
1916	3,514	4,370	82,933	230	4,565							
1917	78	811	24,557	4	358							
1918	4,731	6,741	224,556	401	6,758							
1920	675	5,690	83,180	209	5,569							
1922	2,500	2,375	45,800	48	2,237							
1923	4,057	6,270	113,927	195	7,562							
1924	2,356	4,707	43,823	52	5,031							
1925	853	2,380	101,236		3,362							
1926	392	904	26,436	24	2,342							
1927	669	1,425	8,825	268	1,996							
Lincoln Rock:												
1916	2,350	2,800	34,000		1,567							
1917		669	15,704									
1919	1,764	1,280			1,767							
1922	5,000	3,000	90,000	1,282	3,000							
1923	3,406	1,080	128,188		2,484							
1924	4,117	11,958	92,715		9,759							
1925	1,198	2,461	50,436	1	3,493							
1926	845	703	28,593	1	2,118							
1927	542	731	11,795		3,486							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Luck Point:												
1917	3	628										
1920	1,044	3,144	24,517	240	3,929							
1922			465		1							
1923	1,112	1,126	68,239		2,930							
1924	196	256	8,385		252							
1925	426	1,976	55,870		1,458							
Lyman Anchorage:												
1908			32,800									
1912	431	114	32,397									
1914	2	852	7,565		5							
1915	625	9,061	74,613		448							
1916	21	651	3,489		5							
1917	74	2,338	18,116		21							
1919		226	4,232		185							
1923	137	3,702	20,516		29							
1926	945	2,251	42,740		1,762							
1927	432	432	1,395	15	2,463							
Lyman Point:												
1925	208	2,332	60,478		492							
1926	935	3,631	59,841		1,332							
1927	439	215	172	15	1,830							
McNamara Point:												
1924	1,422	884	4,212	58	3,250							
1925	933	1,006	31,855		1,874							
1926	139	161	1,795		821							
Marsh Island:												
1919	1,609	1,822	38,138	9	4,096							
1920	413	754	2,726	50	1,565							
1923	2,459	824	131,060		3,170							
1924	2,743	1,159	24,123	15	5,411							
1925	3,309	5,365	309,099	4	12,546							
1926	291	275	7,148	1	1,470							
1927	282	233	425	5	1,685							
McHenry Anchorage:												
1921	88		4,039									
1924	125	423	1,516	7	249							
1926	1	722	156		2							
1927	6	1,958	666		82							
McHenry Inlet:												
1913	60	6,784	46,456		898							
1914		21,682	245,081		3,314							
1915	1,210	5,105	132,461		2,933							
1917	35	1,691	3,248		267							
1918	5	2,384	2,685		415							
1920		242	49		146							
1921		3,978	861		782							
1922	1,113	2,212	27,911		1,540							
1923	369	1,619	31,246		309							
1924	422	16,175	70,338		1,391							
1925	12	8,233	13,237		503							
1926	21	6,932	9,178		1,318							
1927		1,163	239		20							
Meyers Chuck:												
1896	1,408				4,651							
1897	2,250		9,874		4,700							
1898	256		11,499		6,838							
1899			8,760		3,211							
1906	150	29	22,809		9,104							
1907	4	23	692		139							
1908	13	28	2,991		1,691							
1909	1,016	11	24,688		3,293							
1910	981	413	11,090		438							
1911	2,000		2,343		8,205							
1915	2,527	7,156	133,733		3,414							
1916	45	1,087	15,174		1,203							
1919	2,412	4,363	78,380	13	3,639							
1920	878	3,835	22,731	42	1,305							
1922	2,573	2,025	45,390	20	2,022							
1923	88	208	6,848		9							
1924	611	1,955	19,734		954							
1925	1,836	14,890	219,517		3,789							
1926	14	79	509		23							
1927	200	500	4,385	1	338							
Meyers Island:												
1925	55		800									
1926	916	3,036	49,189		2,211							
1927	1,029	1,033	20,123		933							
Misery Island:												
1924	1,111	2,062	32,129		629							
1926	622	988	29,933		2,143							
1927	889	815	15,284		611							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Mosman Inlet:												
1908			2,300									
1909	756	4,405	58,032									
1910	1,232	4,572	63,274		2,341							
1911	154	6,024	54,926									
1912	1,668	20,819	179,586		440							
1913	28	3,272	5,383		44							
1914	149	29,814	53,659		35							
1915	101	4,155	62,957		120							
1917	15	1,595	5,956									
1918	44	846	1,475									
1919		7,191	11,192		29							
1921	698	6,186	47,545		266							
1922	219	30,671	52,989		1,047							
1923	116	3,078	53,572		795							
1924	336	17,090	28,625		794							
1925	42	42,631	64,576		35							
1926	35	12,294	25,898	2	109							
1927	46	8,661	2,647		66							
Narrow Point:												
1907			20,000									
1915	129	380	27,371	4	146							
1916	183	4,335	9,556		11							
1917	1,808	3,687	115,906	2	713							
1918	1,571	2,095	28,590	1	1,242							
1919		15	1,051		3							
1920	22	467	1,982		391							
1922	3,930	4,169	92,519	5	3,359							
1923	1,758	3,532	55,031		2,511							
1924	7,837	4,951	78,187	4	11,447							
1925	2,225	9,871	228,836	60	5,179							
1926	683	1,427	45,717	40	4,028							
1927	1,519	3,168	17,692	18	5,533							
Nesbitt, Point:												
1918	3,598	3,449	131,632	22	1,707							
1919	559	650	6,509		958							
1920	1,955	2,401	8,452		1,427							
1922	1,750	5,620	31,742	6	1,500							
1926	6,015	3,831	66,921		17,137							
1927	3,714	1,633	28,450	3	16,656							
Niblack Point:												
1912	1,595	2,085	129,306		2,714							
1913	1,325	5,562	212,960	4	4,167							
1914	72	5,725	37,156	7	3,828							
1915	2,748	4,602	154,256	240	4,206							
1916	3,747	5,041	87,376	398	4,554							
1918	5,538	15,837	304,715	1,467	12,212							
1919	7,739	22,335	217,950	107	26,229							
1920	2,712	29,638	103,897	813	9,579							
1922	7,184	18,432	258,221	607	9,115							
1923	12,533	13,129	388,293	127	15,660							
1924	3,976	14,218	172,321	11	7,091							
1925	3,006	23,818	196,023	390	5,082							
1926	2,363	7,208	184,950	38	7,264							
1927	1,340	1,241	13,586	148	3,105							
Northwest Cove:												
1913	891	2,188	188,007		4,533							
1914	613	9,813	131,373		20,759							
1915	1,534	5,044	341,884		11,226							
1916	2,195	4,691	46,031		10,274							
1917	1,364	3,292	156,671		4,018							
1918	1,625	4,903	120,970		7,097							
1919	3,554	6,171	219,944		11,416							
1920	838	6,210	34,743		3,323							
1922	1,954	3,576	54,129	28	4,346							
1924	1,382	380	9,651		2,326							
1927	118	120	445	2	241							
Onslow Island:												
1918	749	7,854	114,368		4,628							
1919	2,702	9,419	106,499		5,068							
1920	528	4,320	38,392		1,725							
1922	650	2,417	15,186		1,000							
1923	1,857	5,382	107,585		3,522							
1924	2,433	12,944	43,557		3,237							
1925	1,329	4,980	169,190		4,530							
1926	1,880	3,070	97,950	45	3,640							
1927	931	2,063	20,952		2,093							
Quiet Harbor:												
1912	46	22	103,510		40							
1913					741							
1914		71	4,671		38							
1915		1,056	24,370		4							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Quiet Harbor—Contd.												
1916	4	13	825		3							
1917	4,238	8,144	194,813	143	6,168							
1918	746	3,216	28,430	165	3,382							
1919	1,414	2,523	9,844	2	2,184							
1920	1,827	6,250	10,000	966	2,922							
1925	52	187	5,994		33							
1926	18	54	1,705		166							
Ratz Harbor:												
1905	1,000		50,000		100							
1906	1,057	2,884	45,170		955							
1907	3,109	1,466	261,023		2,498							
1909	185	943	300,220									
1910	884	1,755	111,146		1,126							
1911	466	3,367	88,185		92							
1912	3,049	1,950	140,076		3,971							
1913	653	5,109	115,645		807							
1914	43	1,897	36,278		179							
1915	1,614	5,031	290,656		1,659							
1916	237	2,367	83,813	3	386							
1917	1,048	87,951	439,312	4	7,926							
1918	306	9,928	53,571	5	177							
1919	951	9,460	22,872		213							
1920	294	12,974	37,930		875							
1921	163	5,233	42,765		627							
1922	251	566	12,806		18							
1923	1,404	819	68,023		791							
1925	43	1,541	12,398		64							
1926	2,615	3,153	93,559		5,881							
1927	497	775	11,049		879							
Rocky Bay:												
1904	3,788		40,723		2,589							
1905	1,831		40,407		3,851							
1906	1,000	1,000	10,000		2,000							
1907		100	20,000		5,000							
1908	1,400		46		1,562							
1909	1,717	139	25,499		2,132							
1910	6,783			7	8,457							
1911	1,379	1,078	95,460		7,155							
1912	6,773	14,726	140,631		1,141							
1913		188	3,124		310							
1914		2,000	12,000		700							
1915	1,002	1,784	54,568		1,982							
1917	42	131	5,187	7	27							
1918	29	553	5,066		171							
1921			43		137							
1922	30	5,504	22,507		5,002							
1925	35	458	7,291		406							
1926			205		454							
1927	2	4	220		72							
Salmon Bay:												
1896	2,682				19,725							
1897					15,012							
1898					22,000							
1899					25,401							
1900					33,290							
1904	444		4,890		33,285							
1905	2,838		7,204		49,025							
1906	3,006	12,801	19,132		45,198							
1907	2,874	7,747	8,558		86,019							
1908	3,440	2,412	12,032		35,477							
1909	15	2,678	871		43,035							
1910	5,738	3,626	4,120	165	14,201							
1911	316	517	11,426		10,307							
1912	54	257	4,424	16	41,413							
1913		54	54		9,192							
1914		83			3,519							
1915	125	408	7,476	2	23,421							
1916	65	266	6,351		17,620							
1917	474	1,921	8,416		28,600							
1918	213	203	11,741	1	29,736							
1919	16,879	37,124	34,968		29,777							
1920	1,064	16,932	3,813		21,152							
1921	522	268	4,642		3,930							
1922	909	1,603	13,396	38	6,598							
1923	624	934	8,841		39,184							
1924	162	1,406	10,663		16,817							
1926	15	21	850		365							
Screen Island:												
1917		165	6,579		58							
1921	2,324	2,545	60,993		2,783							
1923	2,265	466	134,017		1,345							
1924	1,879	1,836	24,911		3,042							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Screen Island—Contd.												
1925	1,401	3,605	116,959	-----	4,095	-----	-----	-----	-----	-----	-----	-----
1926	782	1,165	33,648	-----	2,490	-----	-----	-----	-----	-----	-----	-----
1927	339	446	6,402	-----	1,777	-----	-----	-----	-----	-----	-----	-----
Ship Island:												
1911	2,982	2,751	327,360	-----	9,332	-----	-----	-----	-----	-----	-----	-----
1912	1,746	6,251	270,723	5	11,590	-----	-----	-----	-----	-----	-----	-----
1913	1,684	1,374	369,459	-----	9,159	-----	-----	-----	-----	-----	-----	-----
1914	2,513	16,491	218,547	1	57,788	-----	-----	-----	-----	-----	-----	-----
1915	3,522	5,737	111,461	82	2,962	-----	-----	-----	-----	-----	-----	-----
1916	8,460	13,860	243,442	281	13,437	-----	-----	-----	-----	-----	-----	-----
1917	13,814	44,970	384,913	210	14,003	-----	-----	-----	-----	-----	-----	-----
1918	15,520	35,933	560,266	711	21,141	-----	-----	-----	-----	-----	-----	-----
1919	35,048	66,753	757,334	1	26,364	-----	-----	-----	-----	-----	-----	-----
1920	4,063	29,648	185,685	202	10,228	-----	-----	-----	-----	-----	-----	-----
1921	4,529	10,413	124,490	72	3,186	-----	-----	-----	-----	-----	-----	-----
1922	23,324	37,856	493,488	156	18,277	-----	-----	-----	-----	-----	-----	-----
1923	17,979	27,970	649,163	3	21,083	-----	-----	-----	-----	-----	-----	-----
1924	19,374	69,252	543,895	573	27,901	-----	-----	-----	-----	-----	-----	-----
1925	11,241	33,309	527,609	446	23,932	-----	-----	-----	-----	-----	-----	-----
1926	7,347	22,034	316,021	833	18,892	-----	-----	-----	-----	-----	-----	-----
1927	6,227	11,573	98,409	694	22,187	-----	-----	-----	-----	-----	-----	-----
Skookum Jim Creek:												
1919	1,230	8,369	117,705	-----	4,481	-----	-----	-----	-----	-----	-----	-----
1922	5,728	4,431	84,399	230	2,860	-----	-----	-----	-----	-----	-----	-----
1923	5,345	7,584	109,956	57	10,426	-----	-----	-----	-----	-----	-----	-----
Snow Passage:												
1912	-----	248	10,071	-----	565	-----	-----	-----	-----	-----	-----	-----
1915	4,135	950	20,176	2,128	2,506	-----	-----	-----	-----	-----	-----	-----
1916	4	479	8	-----	-----	-----	-----	-----	-----	-----	-----	-----
1917	37	6	7,202	-----	1	-----	-----	-----	-----	-----	-----	-----
1918	157	246	6,475	-----	43	-----	-----	-----	-----	-----	-----	-----
1922	452	-----	2,421	184	7	-----	-----	-----	-----	-----	-----	-----
1924	3,760	713	22,913	13	2,549	-----	-----	-----	-----	-----	-----	-----
1925	4,649	4,946	144,230	-----	6,965	-----	-----	-----	-----	-----	-----	-----
1926	4,910	4,135	108,766	1	15,212	-----	-----	-----	-----	-----	-----	-----
1927	1,436	684	13,140	200	9,064	-----	-----	-----	-----	-----	-----	-----
Split Island:												
1915	159	597	56,711	-----	1,773	-----	-----	-----	-----	-----	-----	-----
1917	841	1,091	89,865	-----	1,773	-----	-----	-----	-----	-----	-----	-----
1918	191	724	22,987	-----	541	-----	-----	-----	-----	-----	-----	-----
Stanhope, Point:												
1922	4,000	2,000	46,000	35	2,000	-----	-----	-----	-----	-----	-----	-----
1923	3,587	2,490	112,451	96	4,353	-----	-----	-----	-----	-----	-----	-----
1925	2,288	5,389	89,673	3	4,429	-----	-----	-----	-----	-----	-----	-----
1926	1,213	1,089	32,928	30	2,165	-----	-----	-----	-----	-----	-----	-----
Steamer Bay:												
1904	27	-----	38,490	-----	-----	-----	-----	-----	-----	-----	-----	-----
1907	-----	1,340	32,654	-----	-----	-----	-----	-----	-----	-----	-----	-----
1908	1,000	504	27,000	-----	-----	-----	-----	-----	-----	-----	-----	-----
1909	1,331	1,336	37,907	-----	-----	-----	-----	-----	-----	-----	-----	-----
1910	1,785	8,968	35,229	-----	810	-----	-----	-----	-----	-----	-----	-----
1911	247	6,186	51,055	-----	3	-----	-----	-----	-----	-----	-----	-----
1912	383	3,696	30,939	-----	18	-----	-----	-----	-----	-----	-----	-----
1913	1,372	3,228	56,769	-----	1,694	-----	-----	-----	-----	-----	-----	-----
1914	-----	757	11,170	-----	63	-----	-----	-----	-----	-----	-----	-----
1915	470	13,179	101,573	-----	1,657	-----	-----	-----	-----	-----	-----	-----
1916	201	3,341	13,797	-----	36	-----	-----	-----	-----	-----	-----	-----
1917	197	11,698	29,960	-----	52	-----	-----	-----	-----	-----	-----	-----
1918	816	3,059	13,754	-----	709	-----	-----	-----	-----	-----	-----	-----
1920	922	5,552	16,588	-----	1,880	-----	-----	-----	-----	-----	-----	-----
1921	246	15	1,586	-----	3	-----	-----	-----	-----	-----	-----	-----
1922	2,280	2,589	19,762	894	650	-----	-----	-----	-----	-----	-----	-----
1924	1,693	2,249	16,379	5	4,325	-----	-----	-----	-----	-----	-----	-----
1925	951	11,928	111,653	1	2,004	-----	-----	-----	-----	-----	-----	-----
1926	1,637	2,995	56,294	10	4,270	-----	-----	-----	-----	-----	-----	-----
1927	836	1,549	12,421	26	4,757	-----	-----	-----	-----	-----	-----	-----
Steamer Rocks:												
1918	106	2,517	40,387	-----	1,614	-----	-----	-----	-----	-----	-----	-----
1919	1,015	3,422	31,358	-----	2,485	-----	-----	-----	-----	-----	-----	-----
1925	770	3,694	111,376	-----	4,641	-----	-----	-----	-----	-----	-----	-----
1926	1,216	1,798	45,399	-----	5,419	-----	-----	-----	-----	-----	-----	-----
1927	409	520	2,853	30	1,413	-----	-----	-----	-----	-----	-----	-----
Stikine Strait:												
1913	-----	2,016	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1917	35	1	9,071	-----	-----	-----	-----	-----	-----	-----	-----	-----
1918	3,598	3,449	131,632	22	1,707	-----	-----	-----	-----	-----	-----	-----
1919	8,131	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1923	-----	-----	1,103	10,000	-----	-----	-----	-----	-----	-----	-----	-----
1925	2,453	3,143	171,420	-----	3,268	-----	-----	-----	-----	-----	-----	-----
1926	1,176	4,896	20,936	-----	5,426	-----	-----	-----	-----	-----	-----	-----
1927	1,778	2,748	13,588	131	3,734	-----	-----	-----	-----	-----	-----	-----

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Thorne Bay:												
1889					10,790							
1890	17,000				35,516							
1891	11,698				14,456							
1896	25,000		80,000		5,000							
1908	2,500	2,500	55,400									
1909	3,266	396	28,855		73							
1910	47	7	43,052									
1911	1,845	5,204	36,662									
1912	6,126	23,684	135,467		311							
1913	1,418	4,716	62,714		82							
1914	4,498	16,540	10,176		16							
1915	11,177	49,964	148,276	1	1,000							
1916	5,169	17,833	119,492	9	467							
1917	24,608	18,391	80,854	3	21,793							
1918	17,549	40,366	384,979	35	2,343							
1919	19,740	103,441	66,478	23	4,492							
1920	95	127	121		179							
1922	2,637	6,695	57,961		208							
1923	2,822	3,935	19,083		281							
Three Island:												
1926	625	2,773	28,625		1,658							
1927	945	2,376	18,094	1	2,034							
Three Way Passage:												
1924	2,596	1,624	23,079	232	3,377							
1927	161	399	3,638	2	787							
Tolstoi Bay:												
1906	913	5,789	30,677		14							
1907	1,568	801	20,223		1,860							
1908	7,433	9,118	125,860		530							
1911	78		498									
1912	717	3,208	20,225									
1913	178	6,526	52,276		45							
1914	325	18,708	23,790		88							
1915	1,352	6,776	25,310		159							
1916	1,542	13,137	124,409	1	1,306							
1917	360	18,994	27,354	11	104							
1918	145	3,282	17,984		150							
1919	20	4,790	7,732	4	643							
1920		92	1,300		70							
1922	6	415	413		2							
1923	73	86	8,916		232							
1924	199	1,010	2,896	1	652							
1926	43	991	2,414		6							
Tolstoi Point												
1920	568	4,215	16,727		445							
1923	73	25	5,165		232							
1925	327	2,354	42,454		908							
1926	1,343	4,665	32,325		1,810							
1927	33	996	893		23							
Whale Passage:												
1896	2,050											
1897			225,000									
1905	9,067	750	118,111		1,000							
1906	2,212	6,763	103,995									
1907	895	12,507	136,551									
1908	1,200	5,000	220,000		856							
1909	6,746	26,441	140,710	77	201							
1910	934	7,153	206,888	2	1,233							
1911	4,460	4,593	179,857		881							
1912	5,243	9,656	145,209		3,516							
1913	4,733	31,339	224,455		2,667							
1914	3,167	8,416	84,174		42							
1915	7,752	12,181	199,715		1,612							
1916	9,537	15,060	263,423		647							
1917	2,209	16,514	364,081		506							
1918	2,574	10,750	281,363		1,621							
1919	5,204	40,961	151,925	1	4,981							
1920	1,698	21,144	56,687	1	5,832							
1922	6,301	17,453	221,185	2	1,998							
1923	4,339	8,651	306,074		580							
1924	4,269	7,983	124,279		1,240							
1925	631	9,628	95,183		177							
1926	4,059	10,506	113,135		970							
1927	896	2,832	14,447	10	6,751							
Windfall Harhor:												
1910			16,834									
1913		657	9,455		1							
1914	53	596	7,139		11							
1915	23	174	3,793		48							
1916		1	459									
1917			14,445									
1918	20	2,282	10,274	1	4,552							

Table 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Northern part—Continued												
Windfall Harbor—Con.												
1923	1	355	17									
1926	605	4,949	56,708		1,231							
1927	229	1,165	2,140	19	808							
Zarembo Island:												
1914		27	1,343									
1918		45	166									
1919	91	164	4,289		731							
1920	2,520	2,280	11,178	44	2,188							
1927	943	544	9,174	12	3,841							
Unallocated:												
1905			7,000									
1906	83	9,669	71,826		38							
1907	26	5	12,380									
1908			10,788		4							
1911	10		508		933							
1912			124,800	15,000								
1913	2,971	42,343	657,503		2,693							
1914	2,352	8,974	131,142	40	20,032							
1915	3,847	8,477	214,511		10,881							
1916	6,119	27,491	210,059	384	17,001							
1917	8,246	67,684	565,082	2,700	12,044							
1918	6,993	75,025	568,545	267	23,469							
1919	4,085	27,869	159,029	5	7,133							
1920	10,277	103,263	391,792	19	32,504							
1921	18,433	45,531	441,158		13,848							
1922	258	1,974	31,122		447							
1923	9,081	8,324	729,779		21,810							
1924	4,408	4,950	26,049	15	7,494							
1925	2,711	20,286	299,721	102	6,903							
1926	2,588	10,201	153,828	57	11,779							
1927	3,106	4,986	43,693	71	16,477							
Total:												
1889					10,790							
1890	17,000				35,516							
1891	11,698				14,456							
1896	89,285		80,000		29,375							
1897	49,834		234,874		19,712							
1898	256		11,499		28,838							
1899			8,760		28,612							
1900					33,290							
1904	5,610		135,437	13	51,621	8		21		2		
1905	49,061	29,043	302,368		73,552	1		19		2		
1906	31,675	52,886	412,693	21	75,091	11		23				
1907	26,572	31,553	565,522	2	116,325			21	3,440			
1908	38,485	33,289	513,442		53,328			23	3,635			3
1909	20,150	42,584	670,614	82	54,587	1	100	11	2,045			5
1910	25,334	64,673	537,936	188	46,437	1	150	17	3,175	1	250	5
1911	46,087	69,603	1,278,626	6	61,283	1	80	27	5,315			5
1912	61,622	121,988	1,652,380	15,021	80,212	3	400	33	7,185			11
1913	27,075	132,387	2,073,731	4	47,021	2	200	42	8,600			14
1914	29,833	196,076	1,348,311	95	150,040	1	150	32	6,550	2	300	16
1915	75,489	181,781	2,680,966	2,783	107,222			38	7,110			21
1916	65,067	244,645	1,663,821	1,344	90,122			60	11,358			18
1917	75,301	322,510	2,651,096	3,084	103,497			48	10,120			25
1918	76,683	342,602	3,341,008	9,908	139,909			68	14,030			32
1919	134,719	507,884	2,399,114	171	174,801			51	10,335			24
1920	43,841	382,670	1,287,371	2,839	132,819			48	8,695			34
1921	31,767	80,635	768,640	91	35,749			16	3,550			5
1922	79,678	189,922	1,975,980	6,448	73,496			56	9,215			19
1923	90,389	155,901	3,722,602	10,481	158,724			38	6,600			31
1924	79,204	206,590	1,605,357	1,018	147,209			40	7,155			29
1925	51,879	271,593	3,875,449	1,418	125,296			44	9,140			44
1926	63,124	200,413	2,477,500	1,257	169,500			105	21,000			58
1927	36,233	69,224	479,373	2,330	150,644			23	4,190			69
By lines (included in above):												
1912				15,000								
1915	1,724			2,014								
1918	2,860			6,650								
1922				2,335								
1923				10,000								
Southern part:												
Adams Point:												
1919	1	222	5,090		42							
1925	65		571		1,976							
1926	2,073	1,813	27,243		3,117							
1927	576	1,236	2,291	15	1,853							
Annette Island:												
1904	840		9,664		25,198							
1905	2,140		11,226		21,977							
1906	1,776	242	24,808		14,394							
1907	3,083	66	29,207		9,240							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Annette Island—Con.												
1908	3,234	488	33,068		14,657							
1909	3,124		53,839		20,597							
1910	1,665	52	5,113		22,604							
1911	1,497	122	14,087		12,034							
1913	54	2,513	27,594		943							
1914	1,262	45,454	162,233		2,310							
1915	2,000	8,000	74,000		4,488							
1916	1	13	500		161							
1917	7,605	22,793	193,093	51	7,782							
1918	782	3,875	183,387		851							
1919	17,727	130,939	910,334	1,933	37,072							
1920	4,943	137,911	902,687	668	34,604							
1921	10,545	53,570	930,864	77	19,812							
1922	193	672	15,492		4,281							
1923	3	277	12,642		69							
1924	41	2,400	3,824		18							
1926	16	673	3,092		19							
1927	20	39	359		21							
Bostwick Inlet:												
1904	223		32,246		160							
1907	956	356	44,189									
1908	2,038	851	55,082		840							
1910	2,126	4,696	25,133									
1911	1,303	11,452	46,159		1,867							
1912	2,782	20,373	29,678									
1913			12,715		13							
1914		3,972	8,665		25							
1915			30,000									
1916	9	238	213		55							
1918	2,141	5,770	124,971	55	1,367							
1919	1,495	14,034	107,078	52	5,040							
1921	181	673	18,032		273							
1922	3,741	14,828	117,664	144	4,499							
1923	3,492	5,420	107,566	52	3,304							
1924	1,016	28,556	109,794	39	4,040							
1925	2,447	26,241	149,490	143	2,336							
1926	3,580	11,484	179,470	190	3,732							
1927	646	1,868	9,545	53	1,943							
Bronaugh Island:												
1925	1,549	5,643	129,136	5	2,709							
1926	1,200	2,379	174,910	4	3,165							
1927	236	495	3,441	6	783							
Caamano Point:												
1908	1,681	4,706	263,572		6,775							
1909	714	58,557	236,292		6,806							
1910	3,489	31,106	313,412		19,390							
1911	1,039	8,765	729,245	19	23,791							
1912	4,121	7,596	777,549	2	11,192							
1913	960	1,850	108,700		1,756							
1914	288	2,417	35,233		3,141							
1915	1,562	8,636	305,184		7,380							
1916	2,770	9,220	76,300		7,747							
1917	3,000	8,986	110,000		4,893							
1918	4,380	11,387	353,105	25	7,553							
1919	3,999	19,014	158,892	34	14,751							
1920	1,539	23,905	82,786	17	9,490							
1922	3,097	12,072	129,490	16	3,315							
1923	5,544	8,122	335,571	44	9,734							
1924	2,444	14,398	247,148	11	7,888							
1925	1,093	8,632	142,570	16	2,565							
1926	4,083	14,412	300,015	119	12,432							
1927	1,642	3,469	31,842	26	5,376							
Cedar Point:												
1922		65	7,000									
1923	2,271	6,385	259,121	67	6,904							
1925	1,326	11,834	145,678	169	3,042							
1926	1,255	7,346	264,850	84	4,234							
1927	639	2,817	33,457	333	4,902							
Chacon, Cape:												
1909	156		678		2,609							
1915	2	607	2,346		2							
1917	5,630	16,100	432,185	51	8,204							
1918	38,945	29,765	788,657	691	44,662							
1919	42,360	67,902	1,186,484	686	105,660							
1920	11,863	72,415	705,397	9,848	68,167							
1921	9,377	5,841	209,544	15	57,560							
1922	24,510	51,971	856,976	6,008	22,591							
1923	25,844	28,984	1,224,756	315	26,847							
1924	22,791	66,186	958,037	87	38,795							
1925	15,314	69,388	1,195,808	1,843	30,042							
1926	11,038	7,852	251,467	1,622	5,249							
1927	5,803	3,598	25,917	964	3,720							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Chasina Point:												
1918	1,106	4,133	9,300		434							
1919	2,223	12,701	110,473	32	3,251							
1920	191	1,146	3,854	22	815							
1922	1,514	12,701	99,295	7	2,443							
1923	768	6,085	68,855	43	1,804							
1924	1,643	8,301	75,995		3,989							
1927	615	3,064	2,648		984							
Chester, Port:												
1910	32	900	10,808		20,951							
1911			614		1,177							
1912	1,686		23,230		291							
1913	142		73,303		4,237							
1922	197	82	781	3	868							
1924	2,468	19,896	275,899	148	5,733							
1925	16	5,650	1,132		662							
1926	423	471	410		375							
Chichagof Bay:												
1908	90		700		268							
1918			3,000									
1924		21	1,341		78							
1925	451	12,390	97,502		1,358							
1926	507	1,820	55,865		1,017							
1927	604		154		1,476							
Cholmondeley Sound:												
1904		71,500	117,000		1,569							
1905	560	168,000	98,500		120							
1906	2,955	148,256	210,482		620							
1907	9,789	62,810	366,386		600							
1908	5,140	139,999	451,279	7,548	9,119							
1909	45	14,000	120,500									
1910	557	78,428	476,790		884							
1911	16,907	423,126	1,135,184		19,701							
1912	9,236	963,478	682,769		6,209							
1913	3,175	472,478	503,625		1,409							
1914	4,569	655,803	229,314		2,818							
1915	12,453	326,681	343,312		19,381							
1916	7,112	296,219	65,712		7,527							
1917	6,201	639,278	360,765	6	6,802							
1918	5,480	201,162	119,777	1	2,090							
1919	6,416	269,981	194,489	85	6,416							
1920	485	72,424	50,426	10	2,016							
1921	5,277	158,427	20,884									
1922	1,676	94,340	28,099		1,438							
1923	5,588	82,321	103,748		1,761							
1924	1,822	294,652	100,110		1,070							
1925	2,407	198,839	188,470	1	3,584							
1926	3,072	88,668	58,281	79	1,966							
1927	95	1,304	702	18	582							
Clover Bay:												
1904			50,000									
1907			126,625		600							
1908			50,000									
1910	921	18	106,076									
1911	174	615	83,735		111							
1912	366	5,435	25,703		2							
1913	70		27,727		1,073							
1914	190	8,339	6,544		267							
1915	1,000	11,410	162,491	1	1,099							
1916	794	3,271	39,054		49							
1917	73	329	12,411		32							
1918	62	1,083	2,778		133							
1919	1	1,086	16,474		132							
1922	625	2,820	89,901		2,282							
1923	1,318	20,072	9,411		87							
1924	441	936	4,148	21	2,423							
1925	45	1,102	334		143							
1926	3	30	747		12							
1927	113	164	259		147							
Clover Point:												
1920	259	3,654	11,677	5	1,520							
1926	245	7,021	18,300		736							
Coal Bay:												
1907	817	277	105,857									
1910		1,600	119,804		4,468							
1911	507	2,294	26,713		182							
1912	698		12,769		59							
1913	74	970	12,093		127							
1914		151	287									
1925	492	2,908	5,373		135							
Cow Island:												
1926	990	2,114	100,860		2,973							
1927	580	2,160	4,432	4	2,306							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Dall Head:												
1913	445	202	21,845		764							
1914	68	1,143	7,642		1,823							
1915	10,903	9,330	171,891	205	15,749							
1918	8,104	7,857	243,591	95	6,991							
1919	5,479	15,929	145,569	132	7,894							
1920	4,074	32,370	161,677	240	8,196							
1922	24,567	37,344	567,276	339	13,609							
1923	33,318	105,339	1,380,093	147	44,063							
1924	19,521	45,680	706,285	224	31,616							
1925	19,086	32,732	541,098	361	13,569							
1926	7,789	15,288	581,671	158	11,898							
1927	3,873	11,075	51,974	759	9,935							
Davison Point:												
1922	4,948	3,337	142,000	88	4,988							
1923	3,280	5,051	259,945	46	7,990							
1924	1,886	11,841	122,890	115	4,901							
1925	564	3,577	55,841	32	1,300							
1927	922	3,554	34,125	680	7,888							
Doctor Point:												
1919		2,375	286									
1926	11,961	95,954	345,243	109	13,456							
Dora Bay:												
1894	281		9,810		6,972							
1896	44		8,914		5,695							
1897	600		3,800		9,000							
1904			3,868		14,637							
1905	2,154		14,649		12,743							
1906	2,241	24,034	14,689		6,694							
1907	1,191	7,410	7,053		3,386							
1909	1,411		7,411		2,214							
1910	3,961	124	67,408		6,991							
1911	1,682	2	2,515		3,387							
1912	652	11,656	3,847		1,565							
1913	41		15,741		3,802							
1914	415	3,271	7,461		8,893							
1915	69	4,183	16,784		4,768							
1916	160	6,775	623		3,437							
1917	4	2,275	2,445		142							
1918	397	3,640	3,232		4,676							
1919	27	3,417	1,044		1,524							
1920	15	110	4		78							
1922	817	2,928	23,349	5	900							
1923		121	3,118		1							
1924	38	2,075	2,919		612							
Driest Point:												
1923	1,809	4,750	121,629	65	3,873							
1924	281	2,980	25,320	30	837							
1925	566	4,324	53,528	60	1,393							
1926	595	3,272	117,167	49	2,031							
1927	55	490	3,611	107	863							
Duke Island:												
1904	1,078				4,693							
1905	609				5,980							
1906	844	3	1,084		3,581							
1907	1,606	5	2,265		6,505							
1908	2,755	786	4,829		8,797							
1909	1,853		3,491		6,420							
1910	377		1,856		9,199							
1911	1,359				8,548							
1912	1,163	324	30,754		7,701							
1915			5,696		382							
1917	56	1,845	6,274		944							
1918	86	874	3,575		220							
1920	492	2,571	27,405		1,557							
1922	168	199	253		73							
1923	201	986	28,573		607							
1924	6	7,130										
Gardner Bay:												
1926	414	375	18,402		313							
Grant Cove:												
1919	1,030	3,716	62,837		2,254							
1923	1,472	5,933	9,482	1	461							
1925	1,025	8,709	103,602		1,966							
1926	407	570	20,453		765							
1927	501	1,009	3,660	11	2,072							
Gravina Island:												
1911	147	1,024	24,461		825							
1913	5,150	1,281	333,722		4,635							
1914	3,036	25,481	371,315		33,112							
1915	3,526	20,044	619,987		16,565							
1916	21,095	29,069	354,095	1,044	23,434							
1917	12,442	50,231	279,362	90	12,604							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Gravina Island—Con.												
1918	14,120	30,457	581,624	515	18,874	-----	-----	-----	-----	-----	-----	-----
1919	9,456	24,781	332,831	-----	25,708	-----	-----	-----	-----	-----	-----	-----
1920	2,416	15,959	127,668	339	10,165	-----	-----	-----	-----	-----	-----	-----
1922	7,727	13,315	240,323	127	8,024	-----	-----	-----	-----	-----	-----	-----
1923	14,454	28,063	390,009	42	17,348	-----	-----	-----	-----	-----	-----	-----
1924	9,277	92,318	793,347	127	28,760	-----	-----	-----	-----	-----	-----	-----
1925	12,302	69,524	810,261	1,288	18,025	-----	-----	-----	-----	-----	-----	-----
1926	5,643	26,103	667,471	253	11,849	-----	-----	-----	-----	-----	-----	-----
1927	4,104	10,856	73,097	561	14,105	-----	-----	-----	-----	-----	-----	-----
Grindall Island:												
1923	10,617	16,158	190,551	80	15,451	-----	-----	-----	-----	-----	-----	-----
1924	4,357	10,129	60,731	177	15,847	-----	-----	-----	-----	-----	-----	-----
1925	640	2,330	31,198	30	600	-----	-----	-----	-----	-----	-----	-----
1926	2,448	8,556	98,751	8	10,064	-----	-----	-----	-----	-----	-----	-----
1927	1,733	10,483	18,391	39	5,513	-----	-----	-----	-----	-----	-----	-----
Grindall Passage:												
1909	-----	-----	142,019	-----	-----	-----	-----	-----	-----	-----	-----	-----
1915	254	4,589	31,983	-----	1,087	-----	-----	-----	-----	-----	-----	-----
1916	920	2,183	11,856	-----	1,990	-----	-----	-----	-----	-----	-----	-----
1922	-----	363	12,264	-----	-----	-----	-----	-----	-----	-----	-----	-----
1923	954	1,779	72,823	-----	1,189	-----	-----	-----	-----	-----	-----	-----
1924	589	2,640	32,654	-----	811	-----	-----	-----	-----	-----	-----	-----
Grindall Point:												
1914	6	12,400	100	-----	-----	-----	-----	-----	-----	-----	-----	-----
1916	4,498	10,691	96,601	1,149	6,110	-----	-----	-----	-----	-----	-----	-----
1917	322	668	24,821	-----	252	-----	-----	-----	-----	-----	-----	-----
1918	5,276	11,788	164,546	871	6,763	-----	-----	-----	-----	-----	-----	-----
1919	6,324	6,985	62,626	-----	6,865	-----	-----	-----	-----	-----	-----	-----
1920	1,752	10,780	84,806	431	5,471	-----	-----	-----	-----	-----	-----	-----
1922	6,036	6,131	89,170	251	4,396	-----	-----	-----	-----	-----	-----	-----
1923	1,680	5,770	44,274	218	678	-----	-----	-----	-----	-----	-----	-----
1924	749	2,811	61,203	2	2,009	-----	-----	-----	-----	-----	-----	-----
1925	3,998	20,801	186,830	428	14,779	-----	-----	-----	-----	-----	-----	-----
Halibut Creek:												
1911	207	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1912	26	-----	3,005	-----	59	-----	-----	-----	-----	-----	-----	-----
1913	766	102	10,414	-----	13	-----	-----	-----	-----	-----	-----	-----
1914	43	328	732	-----	10	-----	-----	-----	-----	-----	-----	-----
1915	5	530	19,241	-----	59	-----	-----	-----	-----	-----	-----	-----
1916	227	-----	-----	-----	23	-----	-----	-----	-----	-----	-----	-----
1917	412	-----	-----	-----	23	-----	-----	-----	-----	-----	-----	-----
1918	237	2	1,060	-----	400	-----	-----	-----	-----	-----	-----	-----
1919	50	2	611	-----	141	-----	-----	-----	-----	-----	-----	-----
1920	697	29,996	50,305	-----	5,085	-----	-----	-----	-----	-----	-----	-----
1922	1,836	7,823	130,804	3	1,740	-----	-----	-----	-----	-----	-----	-----
1923	5,276	11,551	171,465	54	8,290	-----	-----	-----	-----	-----	-----	-----
1924	1,608	6,766	57,959	2	2,362	-----	-----	-----	-----	-----	-----	-----
1927	94	23	69	-----	103	-----	-----	-----	-----	-----	-----	-----
Hall Cove:												
1919	-----	-----	29	-----	323	-----	-----	-----	-----	-----	-----	-----
1922	197	14	7,208	-----	591	-----	-----	-----	-----	-----	-----	-----
1923	262	888	7,227	-----	659	-----	-----	-----	-----	-----	-----	-----
1924	19	172	2,054	-----	1,713	-----	-----	-----	-----	-----	-----	-----
1925	5	-----	47	-----	625	-----	-----	-----	-----	-----	-----	-----
1927	104	326	724	50	175	-----	-----	-----	-----	-----	-----	-----
Hemlock Island:												
1904	477	-----	20,453	-----	-----	-----	-----	-----	-----	-----	-----	-----
1905	-----	-----	2,950	-----	-----	-----	-----	-----	-----	-----	-----	-----
1913	-----	-----	3,943	-----	-----	-----	-----	-----	-----	-----	-----	-----
1914	-----	-----	13,978	-----	-----	-----	-----	-----	-----	-----	-----	-----
1922	2	242	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1923	21	257	148	-----	18	-----	-----	-----	-----	-----	-----	-----
1924	-----	521	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1925	-----	453	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1926	237	6,245	267	-----	6	-----	-----	-----	-----	-----	-----	-----
Harris Creek:												
1914	19	56,372	16,413	-----	37	-----	-----	-----	-----	-----	-----	-----
1916	1,429	180	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1918	161	17,840	33,611	15	244	-----	-----	-----	-----	-----	-----	-----
1919	108	10,354	3,012	-----	19	-----	-----	-----	-----	-----	-----	-----
1920	-----	5,721	486	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hidden Bay:												
1924	48	1,312	5	-----	3	-----	-----	-----	-----	-----	-----	-----
1926	89	83	4,117	-----	277	-----	-----	-----	-----	-----	-----	-----
Hollis Creek:												
1914	44	73,659	54,514	-----	176	-----	-----	-----	-----	-----	-----	-----
1916	34	7,123	11,224	-----	50	-----	-----	-----	-----	-----	-----	-----
1917	2,349	6,728	39,652	-----	98	-----	-----	-----	-----	-----	-----	-----
1918	345	29,345	27,197	1	795	-----	-----	-----	-----	-----	-----	-----
Hotspur Island:												
1923	914	1,668	47,816	-----	894	-----	-----	-----	-----	-----	-----	-----
1924	1,238	4,513	93,464	-----	2,493	-----	-----	-----	-----	-----	-----	-----
1925	549	1,535	25,295	-----	743	-----	-----	-----	-----	-----	-----	-----
1926	427	1,333	52,828	-----	1,058	-----	-----	-----	-----	-----	-----	-----
1927	354	681	2,949	2	812	-----	-----	-----	-----	-----	-----	-----

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Ingraham Bay:												
1913	27	-	4,153	-	-	-	-	-	-	-	-	-
1914	-	653	626	-	2	-	-	-	-	-	-	-
1915	5	539	3,489	-	2	-	-	-	-	-	-	-
1916	114	-	-	-	-	-	-	-	-	-	-	-
1919	54	2,312	1,642	-	11	-	-	-	-	-	-	-
1926	425	902	23,897	-	261	-	-	-	-	-	-	-
1927	186	762	1,401	-	769	-	-	-	-	-	-	-
Island Point:												
1911	-	1,470	34,221	-	32	-	-	-	-	-	-	-
1916	16	678	292	-	4	-	-	-	-	-	-	-
1917	11	614	218	-	4	-	-	-	-	-	-	-
1920	1,967	10,201	16,928	-	2,764	-	-	-	-	-	-	-
1921	12,739	90,695	367,887	922	16,548	-	-	-	-	-	-	-
1922	5,982	16,010	176,740	92	4,912	-	-	-	-	-	-	-
1923	1,764	3,425	118,303	-	1,503	-	-	-	-	-	-	-
1924	11,414	79,007	509,730	109	26,091	-	-	-	-	-	-	-
1925	790	10,727	150,408	-	2,304	-	-	-	-	-	-	-
1926	3,174	20,137	148,235	2	4,567	-	-	-	-	-	-	-
1927	2,819	10,615	16,170	721	8,937	-	-	-	-	-	-	-
Johnson Cove:												
1892	40	-	357	-	4,482	-	-	-	-	-	-	-
1893	-	-	15,329	-	4,119	-	-	-	-	-	-	-
1894	-	-	4,083	-	11,863	-	-	-	-	-	-	-
1895	-	-	3,287	-	15,558	-	-	-	-	-	-	-
1896	260	-	14,352	-	10,798	-	-	-	-	-	-	-
1897	2,521	-	54,765	-	8,428	-	-	-	-	-	-	-
1904	-	-	4,841	-	9,136	-	-	-	-	-	-	-
1907	-	-	-	-	5,480	-	-	-	-	-	-	-
1908	-	-	-	-	2,100	-	-	-	-	-	-	-
1910	1,901	1,025	16,306	-	3,889	-	-	-	-	-	-	-
1911	25	13	12,392	-	3,128	-	-	-	-	-	-	-
1912	203	1,570	32,011	-	1,095	-	-	-	-	-	-	-
1913	-	-	887	-	679	-	-	-	-	-	-	-
1915	29	725	6,922	-	6	-	-	-	-	-	-	-
1916	61	75	920	-	507	-	-	-	-	-	-	-
1919	126	988	780	-	-	-	-	-	-	-	-	-
1924	18	10,979	-	-	-	-	-	-	-	-	-	-
1927	17	45	541	-	244	-	-	-	-	-	-	-
Johnson, Port:												
1892	1,310	-	-	-	8,434	-	-	-	-	-	-	-
1893	-	-	1,754	-	17,154	-	-	-	-	-	-	-
1894	2,329	-	-	-	15,525	-	-	-	-	-	-	-
1895	1,979	-	1,465	-	17,874	-	-	-	-	-	-	-
1896	1,900	-	8,000	-	21,700	-	-	-	-	-	-	-
1897	2,957	-	10,016	-	26,310	-	-	-	-	-	-	-
1898	4,324	-	15,596	-	14,279	-	-	-	-	-	-	-
1899	399	-	11,223	-	25,018	-	-	-	-	-	-	-
1900	343	-	11,758	-	19,036	-	-	-	-	-	-	-
1904	3,019	-	7,016	-	13,710	-	-	-	-	-	-	-
1905	3,579	-	21,589	-	9,731	-	-	-	-	-	-	-
1906	3,152	4,370	23,874	-	20,097	-	-	-	-	-	-	-
1907	2,063	130	5,840	-	28,481	-	-	-	-	-	-	-
1908	2,853	939	3,403	-	13,579	-	-	-	-	-	-	-
1909	1,501	1,193	-	-	1,053	-	-	-	-	-	-	-
1910	1,297	197	9,406	-	26,530	-	-	-	-	-	-	-
1911	693	-	17,756	-	8,087	-	-	-	-	-	-	-
1912	1,265	3,563	21,855	-	14,642	-	-	-	-	-	-	-
1913	977	2,790	36,999	-	12,142	-	-	-	-	-	-	-
1914	588	4,259	9,890	-	33,372	-	-	-	-	-	-	-
1915	351	5,164	38,742	-	5,171	-	-	-	-	-	-	-
1916	2,459	2,213	1,513	-	9,350	-	-	-	-	-	-	-
1917	400	7,062	23,657	-	7,437	-	-	-	-	-	-	-
1918	337	2,299	3,294	-	6,096	-	-	-	-	-	-	-
1919	208	3,673	18,791	-	845	-	-	-	-	-	-	-
1920	987	15,451	39,802	-	7,841	-	-	-	-	-	-	-
1922	207	2,136	2,092	-	7,296	-	-	-	-	-	-	-
1923	1,345	2,218	46,454	-	5,902	-	-	-	-	-	-	-
1924	499	3,101	19,647	-	9,018	-	-	-	-	-	-	-
1925	716	6,272	34,779	6	6,251	-	-	-	-	-	-	-
1926	519	8,297	234	-	165	-	-	-	-	-	-	-
Karta Bay:												
1888	1,739	-	-	-	30,020	-	-	-	-	-	-	-
1889	6,027	-	-	-	14,217	-	-	-	-	-	-	-
1890	-	-	-	-	42,788	-	-	-	-	-	-	-
1891	-	-	-	-	68,876	-	-	-	-	-	-	-
1895	1,826	-	-	-	5,631	-	-	-	-	-	-	-
1896	-	-	-	-	84,545	-	-	-	-	-	-	-
1897	2,500	-	36,000	-	23,000	-	-	-	-	-	-	-
1898	14,855	-	25,680	-	106,876	-	-	-	-	-	-	-
1899	4,000	-	114,743	-	55,730	-	-	-	-	-	-	-
1900	6,224	-	185,676	-	63,305	-	-	-	-	-	-	-
1904	-	-	-	-	1,586	-	-	-	-	-	-	-

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Karta Bay—Contd.												
1906	4,000	7,100	276,200		107,061							
1907	5,802	16,503	102,497		64,309							
1908	146	6,764	19,780		3,200							
1909	1,632	44	48,539		55,800							
1910	3,966	419,826	96,690		87,330							
1911	5,508	187,141	238,187	70	47,232							
1912	13,359	283,564	434,417		27,825							
1913	627	128,979	182,822		20,322							
1914	3,696	422,205	147,216	2	44,132							
1915	4,255	155,890	39,787		15,837							
1916	3,810	84,790	50,544	7	16,538							
1917	2,478	52,310	29,560	98	17,386							
1918	1,139	13,918	48,335	1	13,894							
1919	3,054	81,911	68,173		12,144							
1920	125	50,900	24,182		4,418							
1921	991	1,181	23,697		672							
1922	946	25,569	178,040		9,306							
1923	1,487	63,368	40,104	2	1,543							
1924	2,473	155,017	142,936	3	7,036							
Kasaan Bay:												
1889	5,219				1,304							
1905		130,000	24,000									
1906	800	9,000	27,000									
1907			125,287									
1908	7,346	46,788	371,770		35,234							
1910		28,500	115,387									
1911	2,164	1,014	40,348		82							
1912	2,455	1,364	83,251	1	2,528							
1913	1,582	11,375	81,148		272							
1914	942	222,269	52,245		810							
1915	37	11,201	18,515		68							
1916	731	54,210	1,666	1,046	11							
1917	2,796	62,027	72,548		145							
1918	3,392	46,356	90,925	10	3,452							
1919	673	23,956	13,445		172							
1920	1,036	201,917	19,600		570							
1921	423	480	34,581		12,450							
1922	1,664	27,092	53,252	46	1,128							
1923	5,819	76,623	202,757	41	1,759							
1924	1,039	37,538	105,166		1,462							
1925	5,064	86,998	383,767	7	4,679							
1926	5,906	121,802	157,503		2,791							
1927	1,536	11,615	6,232	23	2,263							
Kegan Cove:												
1892	191				16,795							
1893	324		6,365		10,265							
1894	362				18,739							
1895					27,950							
1896	384		5,446		29,775							
1897	840		47,500		23,231							
1904	1,652		17,632		24,096							
1906	1,099	857	19,184		9,475							
1907			17,683		5,009							
1908					6,790							
1911	59		86,697		5,820							
1912	3,363	42,585	59,716		13,703							
1913	981	6,323	57,320		3,648							
1914					984							
1915	97	6,760	34,602		11,582							
1919	1	18,787	18,666		1,950							
1924		221	46,984		28							
1926	217	9,376	232		14							
1927	6	50	50		200							
Kendrick Bay:												
1912		2,304	14,387									
1913	28		20,665		4							
1914	309	1,158	3,585		87							
1915	32	1,892	7,114		107							
1916	186				34							
1917	1	561	993									
1922	6	632	5,490		5							
1923	193	169	8,194		40							
1925		160										
1926	412	2,184	40,808		874							
1927	828	1,927	6,597	13	3,227							
Kina Cove:												
1896					2,018							
1897	470		15,000		1,500							
1898	2,291		5,754		774							
1907	817	277	105,857									
1910	394		15,076		48							
1911	514	2,509	34,506		1,439							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Kina Cove—Contd.												
1912	138	2,652	20,967		371							
1913	25	400	6,707		222							
1914	23	1,041	6,921		39							
1915	3	311	3,310		10							
1918	3	3	6,075		355							
1919		23	133		340							
Kitkun Bay:												
1910		18,000	33,398									
1912	528	13,371	5,427									
1913	583	24,775	48,055		37							
1914		1,297	1,265		21							
1915	79	9,750	19,793		347							
1916	65	13,626	299		26							
1918	184	3,023	9,895	66	171							
1919		1,755	695		11							
1922		410										
1924	59	4,258										
Lancaster Cove:												
1912	94	2,529	15,871		85							
1913	1		2,415		1							
1914	30	8,814	16		7							
1915	194	9,696	36,844		152							
1916	132	22,709	3,130		80							
1917	55	13,494	3,486		39							
1918	5	22	64									
1919		1,375	506		5							
1926	224	1,540	6,968	3	294							
McKenzie Inlet:												
1915	292	10,443	51,502		304							
1916	788	40,011	5,807		309							
1917	69	20,278	12,659		55							
1918	110	17,941	711		72							
1919	3	2,481	1,492		3							
1920		1,405	4									
McLean Arm:												
1907	316		13,035									
1908	368		2,021									
1911	1,410	2,468	46,067									
1913		87	12,365		178							
1914	28	2,347	2,232		49							
1915	187	909	26,307		149							
1916	155	10,230	8,347		93							
1922	15	148	4,119		19							
1923	15	58	578		42							
1925	379	2,413	97,677		1,122							
1926	16	30	3,464		216							
McLean Point:												
1925	1,644	14,295	240,694	9	4,721							
1926	341	916	141,311		1,301							
1927	142	315	2,876	1	164							
Menefee Anchorage:												
1908	44	103	960		257							
1915		196	3,210									
1922	766	1,814	17,006	5	724							
1923	875	2,287	55,497		680							
1924	670	1,490	6,669		267							
1925	273	844	11,179		225							
1926	174	1,384	6,666		116							
Moira Sound:												
1892			2,965		3,168							
1893	200		10,485		6,671							
1894	1,002		808		8,346							
1895			772		14,653							
1896	102		11,864		12,885							
1897	595		7,771		36,934							
1904			22,275		31,784							
1905	8,247		65,314		46,564							
1906	3,058	18,511	35,356		24,044							
1907	5,178	82,350	383,666		23,977							
1908	3,519	26,805	81,642		81,766							
1909	1,744	538	279,876		64,761							
1910	6,120	43,915	211,816		34,925							
1911	7,479	37,256	491,694		29,193							
1912	5,597	41,260	440,847		19,132							
1913	2,420	60,385	206,737		15,168							
1914	5,095	166,067	111,155		59,403							
1915	3,618	114,824	127,444		31,932							
1916	7,926	132,028	82,142		48,994							
1917	5,814	176,707	225,235	1	12,900							
1918	5,519	100,122	77,043	1	40,593							
1919	6,598	279,328	406,023	1	41,271							
1920	2,355	209,614	56,092		10,235							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Moira Sound—Contd.												
1921					4,000							
1922	4,095	143,516	163,330		18,930							
1923	8,787	204,986	398,835	9	14,909							
1924	2,577	276,099	97,479	1	17,002							
1925	1,299	70,453	111,986	9	5,657							
1926	4,103	64,988	205,503		6,976							
1927	692	1,091	2,438	17	2,393							
Nelson Cove:												
1918	7,096	6,607	154,947	122	3,323							
1919	3,868	8,993	100,726	165	7,741							
1920	1,500	16,975	76,975	50	3,977							
1922	2,426	4,028	58,327	99	1,386							
1923	2,026	3,944	104,967	18	2,326							
1924	2,764	6,959	68,055	83	3,849							
1925	2,548	4,559	55,545	14	1,588							
1926	2,563	6,110	229,231	17	4,706							
1927	1,864	3,061	23,381	411	4,847							
Nichols Bay:												
1896	550				31,192							
1897	1,313		54,772		11,218							
1904					9,000							
1905					21,384							
1906					9,929							
1907	809	501	20,552		8,459							
1908	420		6,730		15,134							
1909					14,670							
1910	276		11,869		14,939							
1911	3,098	2,573	63,805		3,791							
1912	3,790	4,010	65,824		8,468							
1913	507	781	52,076		1,375							
1914		389	4,248		459							
1915	337	9,195	23,930		3,741							
1916	1,706	389	4,211		1,616							
1917	100	1,440	3,335	5	5,544							
1918	591	233	1,957		730							
1919	9	7,212	29,434		1,496							
1920					177							
1923	1,006	106	4,118									
1924	2,227	4,661	123,687	14	3,216							
1925	469	4,165	101,118		2,638							
1926	1,357	1,954	104,564		2,131							
1927	1,749	2,935	18,726	38	3,255							
Nichols Passage:												
1906		164	4,616									
1912	1,686		23,230		291							
1914	798	2,356	25,471		3,710							
1915	2,200	14,620	272,770		9,000							
1916	3,636	7,947	93,753	4	5,212							
1917	2,975	8,955	192,231	65	4,236							
1918	953	4,591	257,386	116	2,470							
1919		125	970		10							
1920	1,002	11,011	65,780	9	2,873							
1922	9,328	32,859	598,940	512	14,367							
1923	3,334	8,822	247,645	176	6,662							
1924	442	1,136	57,432	6	928							
1925	281	1,984	24,923	1	586							
1926	1,041	5,855	178,113	119	3,203							
1927	1,661	3,854	26,197	251	3,881							
Percy Islands:												
1923	3,747	12,982	119,111	3	5,067							
1924	3,004	3,722	39,752	3	2,627							
1925	1,047	4,864	45,625	13	1,917							
1926	12	43	6,253		182							
1927	878	2,527	6,064	3	3,400							
Polk Inlet:												
1915	890	15,806	64,559		1,262							
1916	1,125	21,995	9,116		349							
1917	734	18,484	22,261		88							
1918	393	13,377	2,072		142							
1919	578	22,601	80,591		239							
1920	1	840	1		19							
1923	81	705	14,521		171							
1924	143	567	615		43							
Polk Island:												
1926	400	2,041	41,908		679							
1927	185	300	441	8	364							
Sandy Point:												
1914	1	214										
1919	12	4,029	45									
1924	579	4,970	56,687	8	882							
1925	703	6,251	11,656		1,411							
1926	4	24	244	2	51							
1927	14	148	149	1	115							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Seal Cove:												
1914	15	1,046	2,091									
1915	522		50,000									
1917	4,913	3,823	73,706	700	4,000							
1918		40	4,222									
1919	2,050	7,570	83,475	150	7,500							
1920		1,396	1,560									
1921	3,500	8,000	55,000	130	5,500							
1922	2,796	763	14,796	10	1,814							
1923	2,673	4,279	48,594	486	3,144							
1924	2,734	13,093	75,981		2,756							
1925	6,547	14,762	57,926	20	2,244							
1926	912	5,347	74,992		2,874							
Sealed Passage:												
1916		3,113	58,232	41	1,247							
1917	2,400	13,385	58,120	72	2,767							
1918	3,535	7,868	223,556	54	4,641							
1919	702	2,618	40,463		2,213							
1920	1,061	90,064	5,638	110	3,769							
1922	1,988	4,585	124,065		2,073							
1923	214	793	15,440	96	550							
1924	4,210	14,531	225,964	76	5,841							
1926	2,238	5,639	194,142	209	7,727							
Skowl Arm:												
1896	3,850				4,620							
1897	1,300				4,770							
1905			41,000		8,000							
1906	4,000	14,950	275,000		7,200							
1907	1,361	1,074	207,420		3,488							
1908	2,919	2,670	475,378		5,841							
1909			94,000									
1910	2,353	15,105	303,836		5,668							
1911	3,413	49,263	422,945		5,710							
1912	4,135	32,134	294,070		3,110							
1913	1,722	14,172	294,153		2,062							
1914	970	151,861	239,788	2	4,740							
1915	1,226	48,687	253,286		2,403							
1916	1,745	41,436	13,650		717							
1917	2,169	127,166	184,287		957							
1918	567	12,018	20,926	1	671							
1919	2,235	87,280	111,756		2,229							
1920	54	9,838	13,091		785							
1922	72	2,587	13,133		110							
1923	2,024	23,600	108,139	62	155							
1924	1,429	29,180	38,020		723							
1925	5	174	414		3							
1926	1	1,042	1,000		1							
1927	291	944	417		315							
Skowl Point:												
1914	562	4,721	68,805		6,367							
1922	49	739	2,576		4							
1924	258	1,170	28,559		401							
1925	888	29,035	157,824	6	1,539							
1926	1,034	10,145	84,541		1,506							
1927	300	2,295	705		767							
South Vallenar Point:												
1908	99	276	50,700		280							
1912	24,175	49,453	1,495,040	55	48,574							
1913	1,126	4,681	267,521		4,472							
1914	6,967	59,581	272,523		10,578							
1915	1,489	7,796	210,423		5,184							
1918	3,238	7,945	220,674	186	5,658							
1919	797	5,477	35,358	223	5,104							
1920	749	11,522	58,127	279	3,222							
1922	16,192	42,671	605,455	363	19,194							
1923	5,210	10,189	248,731	90	15,511							
1924	2,438	7,540	55,402	54	16,345							
1926	1,591	1,536	82,132	4	1,705							
Stone Rock Bay:												
1915	11	109	5,452		25							
1918	2,355	1,836	46,162		1,866							
1919	703	1,623	12,372		427							
Streets Island:												
1918	3,129	13,360	244,070	343	8,030							
1919	6,147	74,375	471,383	79	31,224							
1920	1,786	25,244	92,989	4	5,868							
1921	9,366	14,391	161,652		9,101							
1922	9,060	23,947	492,120	6	9,826							
1923	6,385	13,337	395,112	69	11,196							
1924	5,229	21,210	234,954	5	7,533							
1925	1,651	15,002	126,788	7	3,483							
1926	4,270	18,140	202,295	45	7,204							
1927	1,120	6,100	4,096	210	3,384							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Sunny Point:												
1906	409	5,027										
1908	553	67,740	13,446		30							
1909	69		65,194		51							
1910			17,680									
1911	5	255	44,316		123							
1913	70	4,174	115,652		319							
1914	389	67,354	17,156		1,895							
1915	307	7,814	70,051									
1918	6	3,890	8,737		132							
1919	2	1,087	667		9							
1923	450	3,424	38,661		382							
1924	218	263	9,754		244							
1927	8	23										
Tamgas Harbor:												
1892					6,114							
1893			3,543		2,328							
1894			2,686		12,032							
1895			5,449		12,357							
1896			2,982		8,795							
1897	40		21,918		13,430							
1898			4,151		22,678							
1899	282		29,115		11,026							
1900	300		17,743		9,517							
1904	800		21,081		20,437							
1905	34		10,877		22,921							
1906	874	1,803	16,845		13,350							
1907	765	1,450	39,599		9,981							
1908	1,244	7,843	14,266		11,029							
1909			5,226		7,742							
1910			4,601		8,382							
1911	1,378		41,686		12,711							
1913					479							
1914		266	2,061		8,010							
1918		19	2,180		30							
1922	142	250	1,230		259							
1923	205	1,471	16,604		997							
1924	180	2,996	21,355		1,675							
1925	18	206	419		942							
1926	178	1,083	15,723		657							
Twelve Mile Arm:												
1906		800	36,000		1,900							
1907	590	921	22,700									
1908	2,560	2,658	44,574									
1910	915	74	88,940									
1911	1,701	30,688	84,614		207							
1912	1,601	20,837	156,924		1,040							
1913	14	11,874	47,108		147							
1914	231	200,441	157,130		134							
1915	582	74,276	80,301		838							
1916	3,781	40,063	98,602		3,044							
1917	2,313	36,687	95,873	1	1,067							
1918	2,146	20,629	18,265		282							
1919	206	40,215	48,058		1,188							
1920	35	11,596	4,708		48							
1922	456	11,148	31,386		133							
1923	439	15,788	42,201	1	154							
1924	110	33,211	45,211	4	285							
1925	75	13,952	14,914		28							
1926	18	6,852	52,609		46							
1927	3	13,614	330		1							
Vallenar Bay:												
1904	159		2,278		2							
1910			307									
1912			45,066		653							
1913			3,270		6							
1914	2,018	17,272	247,634		21,996							
1917	66	362	3,862									
1918	1,552	15,198	134,656		4,227							
1919	6	832	6,488		7							
1920	324	1,100	11,079		1,192							
1922	3,079	2,404	43,592	9	1,344							
1923	14,285	19,161	396,170	247	11,476							
1924		1,876	1,348									
1925	445	4,388	70,484	9	986							
1926	205	1,376	42,373	12	471							
1927	169	480	3,403	13	415							
Vallenar Point:												
1913			6,854									
1914	27	2,112	30,391		1,726							
1919	1,029	4,899	89,078		3,692							
1921	2,329	1,663	86,913		1,110							
1924	151	3,919	12,950	8	556							
1925	4,159	13,090	222,608	260	6,763							
1926	324	1,629	8,798		274							
1927	1,065	3,797	16,727	13	4,559							

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Trap (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Southern part—Continued												
Walden Rock:												
1924	1, 267	13, 147	180, 876	177	4, 869							
1925	1, 609	13, 909	181, 708	188	4, 544							
1926	667	4, 324	154, 890	77	2, 066							
1927	56	417	3, 577	88	580							
Wedge Island:												
1916	1, 489	5, 543	9, 364		963							
1922	1	57	1, 690									
1923	97	12	5, 451		117							
1924	62	2, 437	2, 291		848							
1926	54	142	615		85							
1927	150	37	197		117							
Unallocated:												
1904	29, 077	10, 184	367, 323		158, 733							
1905	7, 148		217, 552		151, 390							
1906	15, 556	18, 540	280, 324		103, 093							
1910	1, 967			24, 610	2, 200							
1911	69	2, 107	471, 415		842							
1912	7, 878	11, 907	524, 075	300	25, 171							
1913	3, 617	4, 686	433, 373	588	3, 616							
1914	2, 353	8, 974	131, 143	40	20, 032							
1915	14, 186	45, 965	1, 164, 196	232	46, 487							
1916	15, 045	57, 035	307, 760	387	17, 494							
1917	35, 410	116, 587	1, 519, 384	2, 597	55, 588							
1918	25, 402	55, 875	1, 401, 353	363	31, 292							
1919	28, 291	129, 989	912, 621	366	61, 057							
1920	20, 755	508, 312	997, 626	373	64, 082							
1921	3, 414	22, 432	139, 528		1, 344							
1922	3, 953	5, 670	8, 643	10, 025	3, 198							
1923	1, 922	2, 284	55, 084		1, 322							
1924	10, 264	64, 599	295, 084	445	27, 416							
1925	11, 657	134, 975	428, 272	400	16, 283							
1926	14, 061	57, 710	713, 242	9, 278	21, 546							
1927	4, 005	12, 080	62, 230	3, 414	22, 073							
Total:												
1888	1, 739				30, 020							
1889	11, 246				15, 521							
1890					42, 788							
1891					68, 876							
1892	1, 541		3, 322		38, 993							
1893	524		37, 476		40, 537							
1894	3, 974		17, 387		73, 477							
1895	3, 805		10, 973		94, 023							
1896	7, 090		51, 558		212, 023							
1897	13, 136		251, 542		157, 821							
1898	21, 470		51, 181		144, 607							
1899	4, 681		155, 081		91, 774							
1900	6, 867		215, 177		91, 858							
1904	37, 325	81, 684	675, 677		314, 741	5		23		8		1
1905	24, 471	298, 000	507, 657		300, 810	2		17				
1906	40, 764	253, 657	1, 245, 462		321, 438	1		27				
1907	35, 143	174, 130	1, 725, 718		169, 515	1	185	29	5, 225			
1908	37, 009	309, 476	1, 943, 200	7, 548	215, 696	2	240	40	6, 885	1	40	
1909	12, 249	74, 332	1, 057, 065		182, 723	1	80	16	2, 880			3
1910	32, 317	643, 566	2, 051, 712	24, 610	268, 398			46	9, 360			5
1911	52, 338	764, 157	4, 193, 362	89	190, 020	3	480	50	10, 025			5
1912	90, 997	1, 521, 965	5, 322, 282	358	193, 766			74	15, 050			15
1913	25, 184	754, 878	3, 031, 702	588	83, 922	1	70	70	14, 055			9
1914	34, 982	2, 235, 487	2, 448, 023	44	271, 165			100	20, 475			15
1915	62, 703	946, 578	4, 395, 464	438	205, 567			88	17, 800			12
1916	84, 019	903, 073	1, 405, 526	3, 678	157, 171			77	15, 345			26
1917	100, 798	1, 409, 175	3, 982, 423	3, 737	153, 989			67	13, 860			38
1918	143, 274	706, 148	5, 620, 911	3, 532	224, 180			125	24, 900			30
1919	154, 048	1, 398, 952	5, 851, 990	3, 938	397, 982			114	26, 000			50
1920	62, 463	1, 586, 348	3, 693, 360	12, 405	259, 004			60	12, 015			48
1921	58, 142	357, 353	2, 048, 582	1, 144	128, 370			11	2, 100			15
1922	145, 074	610, 282	5, 153, 367	18, 158	172, 066			75	14, 370			40
1923	183, 469	820, 011	7, 580, 094	2, 474	237, 640			64	12, 700			46
1924	128, 741	1, 425, 131	6, 237, 715	1, 979	297, 939			105	20, 615			45
1925	106, 207	940, 090	6, 394, 578	5, 325	171, 466			72	12, 670			74
1926	104, 936	666, 410	6, 264, 366	12, 443	165, 433			187	37, 545			90
1927	43, 053	137, 743	506, 592	8, 848	131, 828			19	3, 800			114
By lines (included in above):												
1908				7, 548								
1910				24, 610								
1913				588								
1916				1, 046								
1920				9, 700								
1922	3, 000			15, 798								
1924	34											
1925	1, 227			1, 615								
1926	2, 338			10, 746								
1927	58			3, 757								

TABLE 23.—*Salmon caught and fishing appliances used in the Clarence Strait district, 1888 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Grand total:												
1888	1,739				30,020							
1889	11,246				26,311							
1890	17,000				78,304							
1891	11,698				83,332							
1892	1,541		3,322		38,993							
1893	524		37,476		40,537							
1894	3,974		17,387		73,477							
1895	3,805		10,973		94,023							
1896	96,375		131,558		241,399							
1897	62,970		486,416		177,533							
1898	21,726		62,680		173,445							
1899	4,681		163,841		120,386							
1900	6,867		215,177		125,148							
1904	42,935	81,684	811,114	13	366,362	13		44		10		1
1905	73,532	327,043	810,025		374,362	3		36		2		
1906	72,439	306,543	1,658,155	21	396,529	12		50				
1907	61,715	205,683	2,291,240	2	285,840	1	185	50	8,665			
1908	75,494	342,765	2,456,642	7,548	269,024	2	240	63	10,520	1	40	3
1909	32,399	116,916	1,727,679	82	237,310	2	180	27	4,925			5
1910	57,651	708,239	2,589,648	24,798	314,835	1	150	63	12,535	1	250	10
1911	98,425	833,760	5,471,988	95	251,303	4	560	77	15,340			10
1912	152,619	1,643,953	6,974,662	15,379	273,978	3	400	107	22,235			26
1913	52,259	887,265	5,105,433	592	130,943	3	270	112	22,655			23
1914	64,815	2,431,563	3,796,334	139	421,205	1	150	132	27,025	2	300	31
1915	138,192	1,128,359	7,076,430	3,221	312,789			126	24,910			33
1916	149,086	1,148,018	3,069,347	5,022	247,293			137	26,703			44
1917	176,099	1,731,685	6,633,519	6,821	257,468			115	23,980			63
1918	219,957	1,048,750	8,961,919	13,440	364,089			193	38,930			62
1919	288,767	1,906,836	8,251,104	4,109	572,783			165	36,335			74
1920	106,304	1,969,018	4,980,731	15,244	391,823			108	20,710			82
1921	89,909	437,988	2,817,222	1,235	164,119			27	5,650			20
1922	224,752	800,204	7,129,347	24,606	245,562			131	23,585			59
1923	273,858	975,912	11,302,696	12,955	396,364			102	19,300			77
1924	207,945	1,631,721	7,843,072	2,997	445,148			144	27,770			74
1925	158,086	1,211,683	10,270,027	6,743	296,762			116	21,180			118
1926	168,060	866,823	8,741,866	13,700	334,933			292	58,545			148
1927	79,286	206,967	985,965	11,178	282,472			42	7,990			183

NOTE.—No catches were reported in the years not shown in any division of this table.

Table 23 shows in detail the known catches of salmon in the Clarence Strait district. For statistical purposes the district was divided into two parts—northern and southern—the dividing line extending from a point on Cleveland Peninsula ½ mile east of Niblack Point directly across the strait to a point 3 miles northwest of the southern extremity of Grindall Point on Prince of Wales Island. This line of division was selected because tagging experiments have shown that, in general, the fish taken north of this line enter the strait from the north, while those south of the line enter through the southern entrance to Clarence Strait. The results of tagging experiments in several places in 1924 and subsequent years indicate that an appreciable number of salmon cross this line, but the bulk of the runs in both sections are probably dispersed largely to the streams nearby and to those of the contiguous districts.

The table lists 53 localities in the northern part of the district, the most important of which are Eagle Creek, Etolin Island, Lake Bay, Lemesurier Point, Meyers Chuck, Mosman Inlet, Narrow Point, Niblack Point, Northwest Cove, Onslow Island, Ratz Harbor, Salmon Bay, Ship Island, Steamer Bay, Throne Bay, Tolstoi Bay, and Whale Passage. The unallocated catches in this part of the strait include salmon from 26 minor or unknown localities, as follows: Rocky Point, Barnes Bay, Cadays Creek, Big Bay, Blashke, Center Island, Clarence Pass, Tom Ka Days Bay, Dewey Anchorage, Indian Creek, Kindergarten Bay, Meridian Rock, Point Stevenson, Snug Anchorage, West Island, Forss Cove, Codeys Bay, Thom Cadez Bay, Fire Island, Kamano Island, Mabel Island, Olsen Cove, Rays Island, Stickson Bay, East Island, and Gull Point.

Other combinations were made as follows: "Coffman Island" catches were added to those from Coffman Cove; "Exchange Creek" to Exchange Cove; "Meyers Creek" to Meyers Chuck; "Nesbitt Reef" to Point Nesbitt; "Jim Creek No. 6" and "Jim Creek" to Skookum Jim Creek; "Steamboat Bay" to Steamer Bay. Stikine Strait catches include those reported from Deep Bay, South Beach, Round Point, and Steamer Point.

The localities in which traps were used naturally stand out as the largest producers of salmon in this part of the district. Eagle Creek, as one of these places, attracts attention in that hundreds of thousands of salmon have been reported as from that stream. The data include, however, the catches by traps a mile or more on either side of the mouth of the stream, the elimination of which would reduce the actual catches at the creek to considerably smaller totals. The creek has no estuary but empties into Clarence Strait from a bold shore which affords no protected area for schooling salmon, so that catches by seines are comparatively small. The traps not only take Eagle Creek fish but intercept salmon that are bound to other streams and thus complicate the data and easily convey false impressions in regard to the Eagle Creek fishery. Segregation of such catches are obviously desirable but could not be made with the available information. The reported catches of king salmon in 1918 and 1922 were certainly not taken at Eagle Creek, but for the most part were made by trollers fishing in the northern part of Clarence Strait in the general vicinity of the creek. These faults of allocation were allowed to stand as reported because they at least fixed the place of capture in the northern part of the strait. Most of the catches along the western shore of Etolin Island from Ernest Point to Point Harrington, exclusive of the bays, were made by traps, as is easily recognizable by the catch of king salmon, whereas the places fished by seines show few or no kings, as may be seen by referring to the data for Exchange Cove, McHenry Inlet, Mosman Inlet, Rocky Bay, Salmon Bay, and Whale Passage.

The shore of Cleveland Peninsula between Niblack Point and Lemesurier Point is the most important area in this district for trap fishing. Large catches were made at Niblack Point, Ship Island, and Northwest Cove. These include appreciable numbers of red salmon and give some indication of the extent to which the runs of this species are fished before reaching their final destination, although no information is available to show the localities to which these runs are headed. It seems fairly certain, however, that the few small streams of this shore are not their ultimate objective. If the movement is northward, they are bound probably to Ernest Sound; if southward, to Behm Canal.

The most important red-salmon stream tributary to the northern part of Clarence Strait empties into Salmon Bay. Although it was barricaded regularly for years and abused by reckless fishing at its mouth in a later period, the run survived and showed no serious diminution before 1921, while, in fact, the catch in 1923 was larger than it had been in 11 years. On January 1, 1926, the bay was closed to all fishing for salmon, thus terminating a fishery that had existed for more than 30 years.

The data here presented do not indicate definitely depletion of the fisheries at any locality. Various laws and regulations have had their effect upon catches near the streams, and closed seasons reduced the catches generally throughout the district. In places where the trend of the catches appeared to be approaching dangerous levels special regulations were applied. Barnes Lake and tributary waters were closed on January 1, 1916. On June 21, 1924, Thorne and Tolstoi Bays were closed. The

areas within 1,000 yards of all streams tributary to Whale Passage and the head of McHenry Inlet were closed on January 1, 1925, and on January 1, 1927, the waters within 1 mile of the head of Rocky Bay were also closed. It is not apparent that these closures reduced even slightly the catch in this section of the district. Good catches of all species have been made each year since the economic crisis of 1921. More pink salmon were taken in 1923 and 1925 than ever before, and the catch in 1926 was the largest in any even year except 1918; it was also reported officially that the escapement of salmon into the streams in 1925 was exceptionally heavy and that it was satisfactory in 1926. Large escapements and large catches occurring at the same time are obviously indications of a favorable condition of the fishery.

The table lists 71 localities in the southern part of the Clarence Strait district which have been reported as producers of considerable numbers of salmon. The most important one in point of early exploitation and production of red salmon is Karta Bay, an arm of Kasaan Bay, into which flows Karta River, a wonderful stream in several respects, being 4 miles in length and the outlet of a chain of lakes. For many years this fishery was claimed as a possessory right by the Indian chief Skowl who handed it down to Baronovich, his son-in-law, who operated a saltery at the mouth of the river. In 1888 the catch at this fishery was packed at the Loring cannery and from then on it is likely that the Karta Bay catches were used almost entirely at the canneries. Chum and pink salmon fisheries were also developed here. Cohos have been taken in limited numbers from the beginning of fishing at Karta. After 1910 the catch of red salmon declined rather steadily, and a few years later chums and pinks fell off abruptly, although there was some recovery after 1921. Karta Bay was closed on January 1, 1925.

Kasaan Bay, in addition to the fisheries of Karta Bay, has yet other important fisheries in the bay proper and in Twelve Mile Arm while Kina Cove and Coal Bay have produced sizable runs. Kina Cove was fished for red salmon as early as 1896. The catch from the bay includes salmon reported from several minor localities, as follows: Daisy Island, Kasaan Point, High Island, Logging Camp, Long Island, Long Island Creek, Morgan Beach, Morgans Creek, Morgans Cabin, Morgan Cove, Mount Andrew, Patterson Island, Round Island, Salt Chuck, Sonihart Creek, Sunihat Creek, Sunnyhart Point, and Trollers Cove.

If the data correctly represent conditions at Coal Bay and Kina Cove these localities have been seriously depleted; but if the Kasaan Bay catches include fish from these places, which is not unlikely, there is no means of determining the true condition of the runs here. No catches were reported from Kina Cove after 1919 and none from Coal Bay since 1925. Kasaan Bay as a single district, however, shows large catches of pink salmon in recent years and a fair production of chums.

Cholmondeley Sound has been a large producer of pink and chum salmon, the catch in 1911 exceeding 1,500,000. Thereafter pinks were less abundant, but the yield of chums was well sustained until 1920 which year marks the beginning of a period of much smaller catches of all species, unmistakable evidence of depletion. This led to the closing of Dora Bay on January 1, 1925, and of Sunny Cove on January 1, 1926. Included in the catches of the sound are salmon reported from the following localities: Chomly Point, Divide Head, Hump Island, North Arm, West Arm, South Arm, Babe Island, and Skin Island. In addition, parts of the catches reported from "Behm Canal, Boca de Quadra, and Cholmondeley Sound" in 1911, from "Cholmondeley Sound and Clover Bay" in 1907, and from "Cholmondeley Sound and Moira Sound" in 1919, were allocated to this locality.

Moira Sound and its many arms constitute an important fishing ground in the Clarence Strait district. Available data show that salmon were first taken there in 1892 and that it has produced steadily down to 1927, omitting 6 years from 1898 to 1903 when stream statistics were not collected. Several small streams provide runs of red salmon, the more prominent of which are those at Johnson and Kegan Cove. Both localities were fished exhaustively until measures of conservation were applied, first at Johnson Cove by prohibition of all fishing within 1,000 yards of the mouths of the salmon streams after January 1, 1926, and then at Kegan Cove by complete closure on January 1, 1927. South Arm and Frederick Cove were closed on January 1, 1925, to conserve the runs of pink and chum salmon which were then being fished rather intensively and exhaustively. These fisheries do not show depletion as conclusively as at some other localities in the Clarence Strait district.

The Moira Sound catches include salmon reported from Black Point, North Arm, South Arm, and Nowiskay; those from Kegan Cove include fish from "Regan" Cove.

Fair catches were made in Skowl Arm during the earlier years, but after 1915 they fell off at an alarming rate. This led to the closing of the arm west of Old Kasaan Village and Khayyam Point on January 1, 1925.

Three highly productive areas in this part of the district are Caamano Point, Cape Chacon, and Gravina Island, in all of which traps were used extensively. More salmon were taken at Cape Chacon in the 4 years, 1922–25, than in any other period of similar length in its history, but a tremendous drop in catches occurred in 1926, a year of exceptional production in many localities in this region, and 1927 was an even poorer year. The small catches in 1926 are not understood, as traps at Cape Chacon have always been regarded as occupying advantageous positions for the interception of salmon entering Clarence Strait from Dixon Entrance. The runs of salmon in 1927 were extremely small, a fact that easily accounts for the poor catches in that year. Data for this locality include all salmon that were reported from Landslide, Old Landslide, New Landslide, and Cape Shakan.

Caamano Point at the southern end of Cleveland Peninsula is the northerly point of entrance to Behm Canal. Since 1912 the catches in this locality show wide fluctuations and a falling trend during a period that was marked by a directly opposite tendency in other localities in this same district. The significance of this is doubtful but it is likely that it is the result of changes in the allocation of catches, although it may be the result of depletion or the effect of increased fishing effort in localities past which the salmon must go in order to reach the northern entrance to Behm Canal.

The west coast of Gravina Island shows very large catches during the last 15 years due wholly to the intensive fishing with traps along that shore, which is followed closely by the salmon migrating northward in Clarence Strait. In addition to catches simply reported as from Gravina Island large numbers were caught at Dall Head, Nelson Cove, Grant Cove, South Vallenar Point, Vallenar Bay, and Vallenar Point. Only a small part of the fish captured in this region is presumed to be going to the small and relatively unimportant streams on Gravina Island. The catches undoubtedly consist largely of fish that are bound to Behm Canal, Ernest Sound, and the northerly waters of Clarence Strait. The Grant Cove catches include fish reported from "Grant Creek" and from "Six Shooter Grant"; Vallenar Bay totals include catches at South Vallenar Bay and "Volmer Bay."

Other combinations of catches in this part of Clarence Strait were made as follows: Chichagof Bay totals include fish from Chichagof and from Chichagof Point; Annette Island fish from Tain; Johnson Cove salmon from Johnson Chuck and Johnson Creek; Nichols Bay data include a catch reported from Bean Island; Nichols Passage catches were increased by the inclusion of fish from Blank Inlet, Blank Point, Bostwick Point, Dall Bay, Gravina Point, and Metlakatla; Tamgas Harbor and Sextant Point catches were combined under the name of the former; and Skowl Arm catches include the salmon reported from Dolion Mine, Shore Bay, and Tom Skowl Place.

The unavoidably large unallocated catches in the southern part of Clarence Strait were augmented further by including therewith the catches from 23 minor or

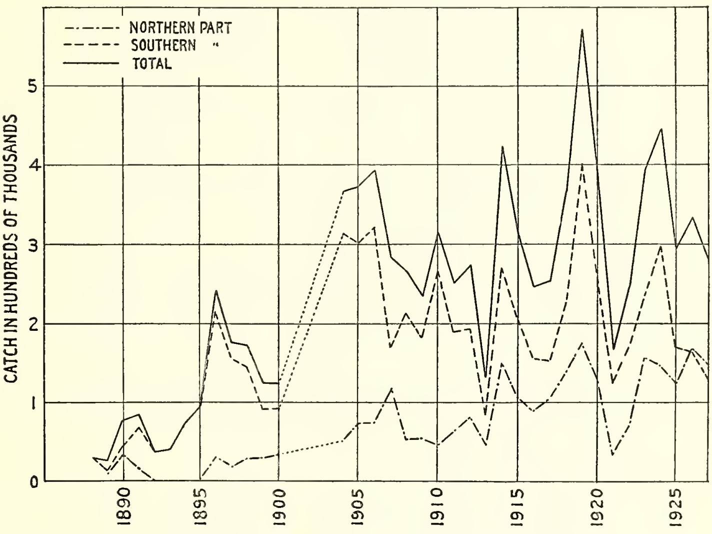

FIGURE 41.—Catch of red salmon in the Clarence Strait district, 1888 to 1927.

undetermined localities, as follows: Perry Jenkins Trap No. 1, Coal Creek, Brendable Trap, West Arm, Whiterock, Steve Selig, Prince of Wales Island, Luke Point, Hundred Thousand Creek, Granville Pass, Island Bay, Twenty Thousand Bank, South Arm, Perry Point, McKinley, Whitestone Creek, Mohaney Creek, Point McCartey, Mallard Bay, Guard Island, Little Dall Island, Point Nunez, and Windy Point. In addition, a division of certain catches that were reported from "Loring and vicinity" in 3 years, 1904 to 1906, increased the unallocated figures in those years.

Figure 41 shows graphically the total catch of red salmon in the Clarence Strait district and the subtotals for the northern and southern parts. Leaving aside the catches previous to 1904 it appears that the production of this species in the southern part has not changed markedly during the period 1904–27. The peak was reached

in 1919, but there was no material decline in catches until 1925, a result which was probably brought about by the closing of practically every locality in which red salmon were taken in this section of the district. The catches in the northern part, however, show a distinct upward trend which is reflected in the more moderate upward trend in the total catches in this district. Previous to 1926 the aggregate catch in the northern part was always well below that of the southern part but in both 1926 and 1927 the catch in the northern part slightly exceeded that of the southern part. No definite reasons can be assigned for this shift in the relative importance of the red-salmon fisheries in the two parts of Clarence Strait. So far as can be seen there has been no corresponding shift in the relative intensity of fishing. Gear, especially the

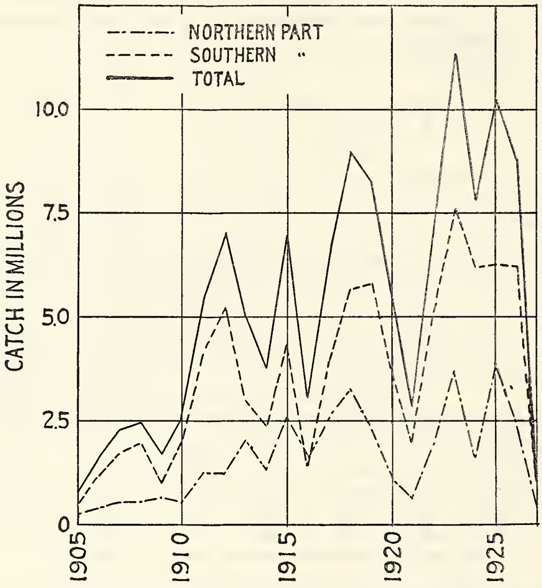

FIGURE 42.—Catch of pink salmon in the Clarence Strait district, 1904 to 1927.

number of traps, has increased rapidly throughout the period 1904–27 but about equally in the northern and southern sections. It is not known whether the fisheries in the two sections draw upon the same runs of fish or not but if they do the continued encroachment of the northern fisheries must ultimately result in the reduction of the catches in the southern part of the strait.

The unallocated catches of pink salmon in these waters has reached tremendous totals. During the period 1892–1917 inclusive the unallocated catches aggregated over 34 millions and during the 10-year period 1918–27 nearly 50 millions, 27 million of these coming in the last 5 years notwithstanding the fact that the catch in 1927 was only 506,592 and that during this period fishing was more restricted by closed waters, closed seasons, and limitations of gear than it had been in all the preceding years of

the history of the industry. Partly on account of these large unallocated catches it is impossible to make a detailed analysis of the catch, but the figures for the district as a whole are interesting. The catches from 1904 to 1927 are shown graphically in figure 42. With the exception of 3 years in which the catch was exceptionally low the general trend has been upward in both the southern and northern part. The small catch of 1921 was, as has been repeatedly pointed out, due to economic conditions. That of 1927, however, was unquestionably due to poor runs—a condition which prevailed generally throughout southeastern Alaska. The catches of pink salmon in the southern part of the strait have been consistently higher than those in the northern part, falling below in only 1 year—1916.

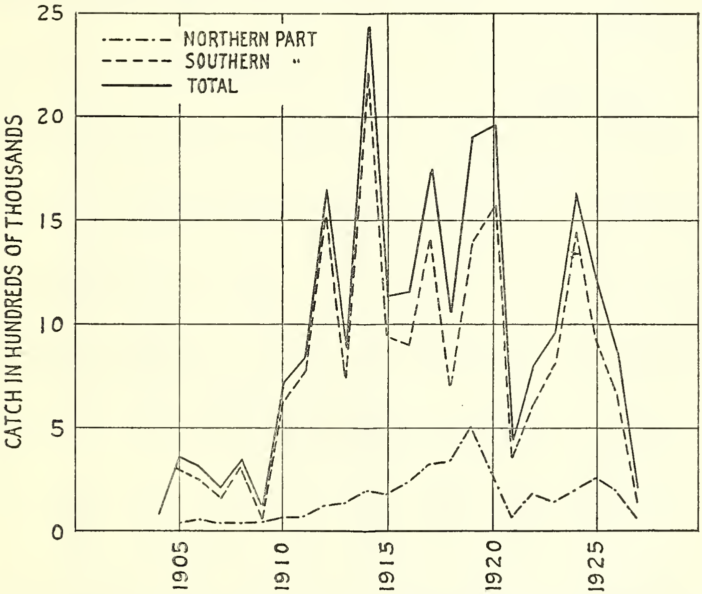

FIGURE 43.—Catch of chum salmon in the Clarence Strait district, 1904 to 1927.

The catches of chum salmon fluctuated widely and abruptly throughout the entire period for which data are available, but it is doubtful that there were corresponding variations in the runs since this species was not especially sought after in the years when pink salmon were abundant. Figure 43 shows the catches from 1904 to 1927. It is very clear that the southern part of Clarence Strait is much more productive of chums than is the northern part, the difference being much more marked than in the case of the pinks. The catch of this species has apparently not yet fully recovered from the drop in production that occurred in 1921 as the average catch in the period 1922–27 is distinctly below that of 1910–20 in both parts. It is doubtful, however, that this is indicative of real depletion for the reason given above.

The catch of cohos has increased tremendously during the period under consideration as shown in figure 44. There was no great difference in the northern and southern parts of the strait up to about 1920, but since then the catches in the south have averaged approximately twice those in the north—just the reverse of the conditions with respect to the red salmon.

The catches of king salmon have never been large and, so far as our records go, have been very irregular. It is interesting to note that there have been periods in which years characterized by very good catches of kings alternated with years in which the catch was very small, and that in every case the large catches were made on even years. This is suggestive of some sort of an association between the king and pink salmon fishery (since the pinks are exclusively 2-year fish) but no such association can at present be pointed out.

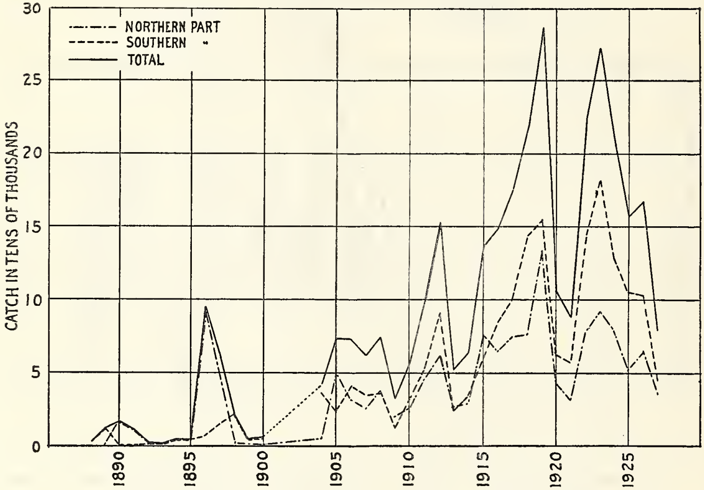

FIGURE 44.—Catch of coho salmon in the Clarence Strait district, 1888 to 1927.

The Clarence Strait district as a whole surpasses all other districts in southeastern Alaska in the total production of salmon. The only indication of weakness in its fisheries is shown in the catches in 1927, a year of poor runs generally in the southeastern area. The fishing effort in 1927 was certainly not lower than in previous years, as 183 traps and 42 seines were operated as compared with 118 traps and 116 seines in 1925, yet the total catch in this district was only a little over 1½ millions as compared with nearly 12 milllions in 1925. The catches of kings, cohos, and reds were not materially lower but those of the other species were far below their normal levels. Just why there should have been poor runs of pinks and chums in the same year is problematical, but there can be no doubt that the fact is of biological significance. It is well known, of course, that the pinks are exclusively 2-year fish while the chums vary mainly from 3 to 5 years in age at maturity. Poor runs of both species coming in the same year may have been merely coincidence; but if not it

would seem to indicate that conditions in the ocean had affected their survival since it is unlikely that unfavorable conditions in fresh water would have been so distributed over a number of years as to have brought about this result. The facts that both species make the seaward migration as soon as they come out of the gravel in which the eggs are laid, that they spend practically all their lives in the sea and have somewhat similar feeding habits, lend some support to the hypothesis that the coincidence of poor runs may be the result of oceanic conditions affecting the survival of both species equally.

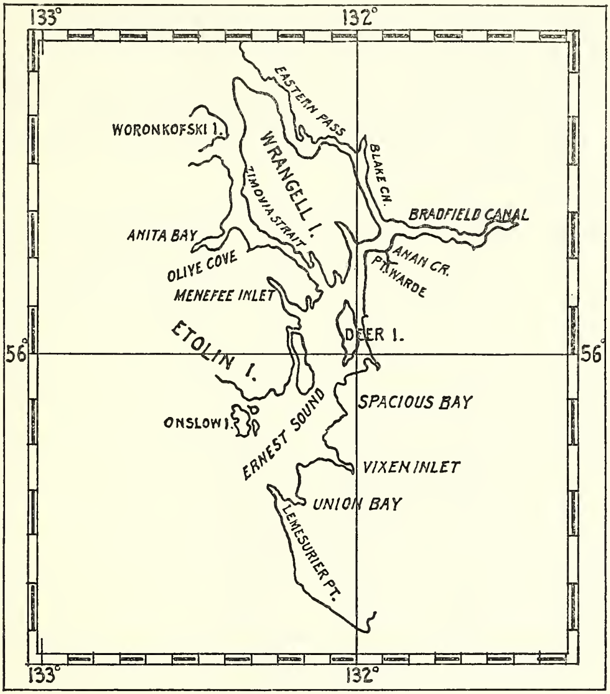

FIGURE 45.—Map of the Ernest Sound district.

ERNEST SOUND DISTRICT

This district includes the waters northerly and easterly of a line from Lemesurier Point to Ernest Point, thence across Onslow Island to the southern extremity of Etolin Island, thence along the watershed of that island to its northern extremity, and thence across Chichagof Pass to East Point on Woronkofski Island and the boundary of the Stikine River district across the northern end of Zimovia Strait and Eastern Passage. (See fig. 45.)

Many small streams are tributary to the several bays, inlets, and coves of the district and support small runs of salmon. The few large streams of the district are tributary to Bradfield Canal, easterly of the intersection of Blake Channel, but they support only small runs of salmon. Anan Creek, one of the most noted pink-salmon streams of southeastern Alaska, is located in this district.

It is not known when commercial fishing began here. Available records indicate that salmon were taken from these waters for canning purposes as early as 1895, and presumably as early as 1887, the year of the opening of a cannery at Gerard Point near the mouth of the Stikine River, but here, as in nearly all other districts, the canneries were preceded by salteries, the operations of which were not recorded, leaving the date of the inception of the industry doubtful. The salteries were primarily interested in pickling red salmon and the first canneries centered their attention on the same species exploiting the runs to streams in the immediate vicinity of Wrangell. When utilization of the other species commenced, fishing became quite general throughout the district and brought about the establishment of canneries at Union Bay, Santa Anna Inlet, and Point Warde, while plants in adjacent districts extended their operations into this field.

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Aaron Creek:												
1907	350	2,854	21,855	218	144							
1913			7,100									
1917	14	74	13		1							
Anan Creek:												
1897			375,000									
1905					200							
1906		35,184	23,651	98	33							
1907	1,620	11,489	891,194	1,036	1,789							
1908	124	37	155,083	50	1,009							
1909	616	2,377	1,033,490	829	54							
1910	2,088	20,747	640,536	24	75							
1911	1,108	39,453	855,711	228	216							
1912	281	4,739	290,701	345	337							
1913	55	2,333	277,192	4	160							
1914	392	6,172	148,735	1	377							
1915	214	13,721	410,813	52	1,258							
1916	741	5,960	319,697	62	803							
1917	814	14,931	100,192	91	1,303							
1918	521	11,511	204,028	31	2,208							
1919	837	2,459	104,878	59	1,643							
1920	14	474	2,983	3	327							
1921	46	167	49,543		320							
1922	1,742	9,982	213,094	110	2,716							
1923	1,993	8,646	461,992	28	9,137							
1924	286	4,509	90,424	39	1,265							
1925	488	14,647	176,343	145	1,813							
Anita Bay:												
1907		959	1,892		14							
1908		409			4							
1910	12	475	6,388									
1911	93	925	43,802		3,191							
1912	82	9,203	13,063		65							
1913	8	2,744	14,545		10							
1914		7,144	9,259		361							
1915		4,827	13,248		1,058							
1916	64	5,842	29,750	3	1,994							
1917	23	3,380	9,219		407							
1918	55	17,834	11,893		2,288							
1919	1	1,163	2,156		592							
1920	55	1,776	637		354							
1922	448	1,517	16,980		593							
1923	61	1,284	12,524		3,467							
Blake Channel:												
1916	387	2,014	21,876	47	48							
1917		1,612	285	6	32							
1918		194	1,979		2							

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Bradfield Canal:												
1912	1,684	1,928	46,998		242							
1915	20	3,561	81,190		364							
1916	946	1,590	68,601	74	358							
1917	1,997	11,154	40,926	84	154							
1918	199	30,521	68,898	58	474							
1919	402	2,614	30,340	48	1,327							
1920	13											
1923	872	287	8,812									
1924	47	8,073	17,245	1	474							
1925	654	3,634	53,500	30	1,872							
1926	465	5,387	60,669	34	2,648							
Brownson Island:												
1925	1,247	11,582	107,581		2,217							
1926	604	5,158	42,006		1,763							
1927	188	1,586	5,052	11	185							
Canoe Passage:												
1907	54	5,703	39,036	4								
1908	142	80	28,487		13							
1909	23	45	7,860									
1910	241		20,339		12							
1911	636	294	128,729		260							
1912	668	9,873	42,119	186	104							
1913		2,292	35,650		51							
1914	188	4,271	35,465		389							
1918	50	107	2,822	10								
1919		230	338									
1921	115	90	7,531		5							
1922	2	189	2,858		1							
1923	103	113	38,999		264							
1924	15	2,518	1,381		6							
1925	7	3,654	7,812		171							
1927	88	941	4,660		31							
Crittenden Creek:												
1915	67	6	11,135		4							
1916	1		658									
1923	184	12	7,268		1							
Deer Island:												
1908					1							
1915		54	600		100							
1916	7	146	4,238		4							
1919				200								
1926		1	45									
Eagle Point:												
1925	449	2,145	31,345		272							
Eastern Passage:												
1915		535	12,419		11							
Eaton Point:												
1914		947	9,378		171							
1919		135	1,409		162							
1920		333	1,301		118							
1923	258	2,010	63,814		570							
1924	62	1,830	7,798	17	175							
1925	1,066	11,654	151,990	14	2,106							
1926	1,115	9,073	92,239	19	5,692							
1927	1,222	3,952	53,104	149	2,185							
Emerald Bay:												
1910	5		14,212		20							
1911		11	9,921		2							
1912	108	145	21,734		28							
1913		389	36,049		175							
1914		2,682	17,910		130							
1915	19	242	8,434		119							
1916	5	336	9,631	3	20							
1917	15	348	27,888		36							
1918	53	125	477									
1920		7	1,334		5							
1922	4	15	2,352		5							
1923	285	613	57,211	1	304							
1924	14	1,216	2,847		24							
1925	1,031	10,011	136,807		2,121							
1926		115	258		6							
1927	391	1,322	16,231	17	680							
Fools Inlet:												
1907	427		34,213									
1908	26	53	56,323	1	166							
1909	7	12	22,976		5							
1910	935		9,379	1	11							
1911		14	7,108		2							
1912	426	53	27,472		68							
1914		6	3,521		1							
1916	1	318	7,631	3	33							
1918	6	62	10,447		23							
1920		685	100		3							
1922	35	643	30,535		50							
1927	1	6	96		1							

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Frosty Bay:												
1910	1		3,790	1	1							
1911	2	97	56,646		74							
1912	19	21	15,243		47							
1913		39	10,207		6							
1914		667	7,013	1	35							
1915		173	3,153	1	28							
1916	1	5	1,782		9							
1918		67	340	2	14							
1921	35	40	6,369									
1922	43	405	27,032		641							
1923	33	386	30,449		64							
1924	19	541	3,943		38							
1925	18	708	9,065	48	107							
Konks Creek:												
1907		314	3,165		2,469							
1908					1,020							
1909			55		1,060							
1910			237		3,010							
1916	36	525	2,505		1,401							
1917	33	525	4,290		1,998							
1918		109	435		1,009							
1920		692			35							
1921			1,593		370							
1922	68	206	863		516							
1923	7	21	692		1,752							
1924	11	2,413	278		6,134							
Kuakan Point:												
1927	16	276	2,470	3	75							
Menefee Inlet:												
1906	11	12,734	11,322									
1907	7	2,764	4,519		4							
1910	1,041	43	33,581		99							
1911	925	1,760	202,096		146							
1912	314	339	34,927		163							
1913		224	21,626		41							
1914	560	6,672	7,428		46							
1915		1,882	1,876		32							
1916	133	29	1,527		2							
1917	53	4,432	13,491	7	74							
1918	4	5,615	3,337		23							
1919	1	2,137	1,994		10							
1920	1,270	9,026	44,299	100	5,100							
1922	25	1,001	1,620		20							
1924	29	14,542	8,624	9	101							
1925	1	3,805	1,169		16							
1927		720	262									
Mill Creek:												
1919		14	305		95							
Olive Cove:												
1904			36,000									
1905	1,500		60,000									
1906	1,000		1,500									
1907	450		38,000									
1908	1,800		57,000									
1909	1,500		15,000									
1910			51,500									
1912	334	294	25,237		382							
1914		808	68,335		43							
1915	332	3,879	72,726		849							
1916	308	1,143	160,852		78							
1919	104	1,965	15,618	11	1,585							
1920	33	1,450	3,160	13	537							
1921		15	3,025		256							
1922	1	580	10,548		102							
1923	18	2	876		669							
1925	3	33	5,222		8							
Santa Anna Inlet:												
1906	146		4,336									
1907	243	19	7,608	7								
1908	443	2	9,552		35							
1911	1,216		7,058		2							
1912	2,004	4	6,381		10							
1913		320	10,256		45							
1914		2	2,726		37							
1915	180		3,570		125							
1916	345	20	7,996		40							
1917	26	1	312		10							
1918	182		663		13							
1920		419	1,265		73							
1923	6	2	1,612		7							
1925	1	133	3,960									
1927	1	64	176		2							

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Seward Passage:												
1912	5		2,297									
1918		1,076	2,758	1	18							
1919	2	64	1,965	16	37							
1921	20	29	6,881		245							
1923	60	211	22,750	2	904							
1924	1,110	21,556	208,452	74	2,388							
1925	111	1,208	25,483	3	160							
1926	158	3,789	34,645	17	1,365							
1927	110	1,599	9,683	62	451							
Snake Creek:												
1915	16	1,737										
1916		6	2,010		1							
1917	1	2,956	57,363	8	86							
1918		1,018	21,324		248							
1921	1,568	553	38,065		1,229							
1922		38	3,705		16							
1923		103	1,924		33							
1925	47	575	29,108		84							
1926	19	170	1,216		85							
Southeast Cove:												
1907	44	11	5,195									
1909	16	5	2,424									
1910	49		2,512		19							
1911		5	8,166		40							
1912	247	95	17,252		151							
1913	136	3,733	146,053		1,287							
1914		1,084	14,609		768							
1916		2	48									
1921			1,122		16							
1922	139	404	37,752		927							
1925		57	1,077		22							
Southwest Cove:												
1908	43		4,574		39							
Stones Island:												
1922		161	2,192		1							
1926	5	216	568		2							
1927		136	122									
Sunny Bay:												
1907	130	650	114,573		284							
1908	138	83	67,622		90							
1909	2		37,500		14							
1910	27		46,834		72							
1911		262	68,884		97							
1912	85	436	24,883		6							
1913		376	47,662		352							
1914		4,928	68,523	2	925							
1915	252	7,626	166,214	24	3,595							
1916	111	1,689	43,913		423							
1917	628	7,443	95,472	4	1,274							
1918	311	3,760	73,433	2	1,043							
1919	53	1,205	18,289	10	509							
1920	26	201	7,091		65							
1922	19	185	5,827		27							
1923	23	45	4,236		70							
1924	24	370	3,406		35							
1925	61	5,016	34,983	5	245							
1926	76	1,571	4,713		66							
1927	53	786	5,115	8	92							
Thoms Place:												
1897	1,992		42,169		17,138							
1898	5,000				10,000							
1900	7,651		74,000		24,661							
1906		580	3,249		22,177							
1907	2,652	310	79,007		20,057							
1908	9	89	11,062	7	12,926							
1909		11	7,753		7,985							
1910			2,923		3,246							
1911	264	274	69,872		10,259							
1912	9,058	3,074	158,691		30,953							
1913	385	1,220	43,167		10,663							
1914	228	2,127	19,506		10,857							
1915	486	1,006	63,957		13,807							
1916	278	224	19,459	1	4,125							
1917		1,485	6,860		4,817							
1918	225	16,913	31,658	5	6,596							
1919	605	2,673	21,049		14,870							
1920	1	345	1,840	1	3,553							
1921			599		1,337							
1922	52	414	10,800	37	2,920							
1923		2	904		5,046							
1924			74		1,472							

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Union Bay:												
1896	1,408				4,651							
1897	2,250		9,874		4,700							
1904	19		20,739		415							
1905	1,889		10,386									
1906	77	15	14,512									
1907	2,079	4,079	198,797	2	780							
1908	663	110	80,854	2	2,868							
1909	1,032	8	80,407		1,634							
1910	3,652	30	32,487		119							
1911	1,430	1,339	35,418		37							
1912	1,679	533	92,032		1,382							
1913	443	1,835	139,470		738							
1914	2,486	6,928	113,067		8,411							
1915	1,778	2,790	160,230	2	5,009							
1916	1,344	4,087	65,383	72	3,021							
1917	3,236	8,234	236,833	775	5,355							
1918	579	9,492	26,487	400	918							
1919	9,828	19,356	301,014	4,616	17,536							
1920	6,775	74,368	166,955	223	15,161							
1921	1,270	3,398	21,064		126							
1922	6,794	6,914	139,946	363	6,120							
1923	7,367	10,489	373,800	63	15,116							
1924	6,777	11,367	93,732	88	13,746							
1925	9,205	20,451	285,870	38	8,254							
1926	2,457	3,515	92,550	86	12,582							
1927	1,837	4,552	34,154	53	4,336							
Union Point:												
1923	5,247	1,808	138,597		2,022							
1924	1,662	3,605	43,025		2,964							
1925	516	4,013	68,553	4	1,189							
1926	927	3,552	51,543	8	6,897							
1927	609	1,271	26,624		1,079							
Vixen Harbor:												
1924	105	833	4,134		72							
Vixen Inlet:												
1907	180		47,750									
1908	71	370	39,329		15							
1909	3		30,434		13							
1910	3,616	2,993	141,066	119	2,790							
1911	1,234	2,179	171,361	15	6,325							
1912	3,488	1,008	79,270		1,930							
1913	1,984	3,900	179,031		2,598							
1914	834	9,016	97,360	22	6,922							
1915	1,449	2,788	101,957		4,132							
1916	1,008	1,683	46,556	65	1,865							
1917	1,389	3,693	91,567	72	1,272							
1918	150	652	8,787	78	238							
1919	1,259	7,203	40,577	13	2,677							
1920	96	371	3,388	36	286							
1922	11	807	2,122		3							
1923	1,280	3,024	64,734	4	1,617							
1924	481	4,902	22,745	5	1,417							
1925	108	1,303	29,619	5	359							
1926	171	1,362	17,945	11	2,762							
1927	69	615	3,815	4	226							
Vixen Point:												
1906	435	462	94,995									
1926		13	868		4							
Warde, Point:												
1906		3,769	7,520	3	16							
1907	151	1,501	58,422	20	170							
1908	23	69	15,187	1	25							
1909	47	851	114,549	26	173							
1910	31	6,173	199,421	24	289							
1911	130	12,485	632,737	41	7,511							
1912	7	14,892	171,714	13	4,624							
1913	299	14,208	433,308	27	732							
1914	630	31,391	190,848	28	2,203							
1915	680	19,407	472,779	96	4,248							
1916	193	6,249	170,962	123	2,913							
1917	964	18,087	64,129	17	1,233							
1918	259	8,943	112,408	26	1,467							
1919	387	3,667	92,082	32	3,219							
1920	128	3,950	15,966	68	867							
1921	162	3,576	78,426	6	2,238							
1922	2,448	15,994	248,339	43	2,899							
1923	916	6,511	181,699	16	4,552							
1924	1,575	17,014	99,775	58	1,749							
1925	16	1,567	19,579		155							
1926	22	1,141	10,728	5	425							
1927	41	1,127	4,397	38	139							

TABLE 24.—*Salmon caught and fishing appliances used in the Ernest Sound district, 1896 to 1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Watkins Point:												
1925	67	183	5,004		65							
1926	166	2,536	28,676	28	2,041							
1927	188	1,720	16,028	91	635							
Zimovia Strait:												
1912			9,125		434							
1913			5,537									
1914	71	1,498	14,606		7,997							
1915	14	98	22,218		339							
1916	268	1,799	72,202		3,509							
1917	85	5,295	139,653	2	2,328							
1918	709	1,266	44,829		3,552							
1919	408	8,884	16,249	7	13,673							
1920	181	27	292		13							
1921			3,707		370							
1922		199	3,063									
1927		6	3		49							
Unallocated:												
1906	195	462	98,919									
1907	69	7	38,892		9							
1908	146	81	43,475		44							
1909	16	3,238	78,917		14							
1910	2,474		30,243	22	390							
1911	290	4,818	120,887		1,254							
1912	4,929	83,765	405,712	28	5,564							
1913	62	369	17,866	170	47							
1914		2,042	2,089	10	3,382							
1915	1,260	22,311	370,418	2	5,319							
1916	3,135	7,677	270,657	75	9,911							
1917	244	7,656	175,457	3	302							
1918	2,944	21,985	161,057	3	3,403							
1919	41	4,802	5,590	3	762							
1920	510	31,874	67,376	134	4,624							
1922	7	66	10,027	2	2,631							
1923		62	1,349		15							
1924	2,401	12,907	101,669		1,865							
1925	857	23,926	203,170	158	3,659							
1926	376	2,969	49,208	54	3,274							
1927	477	6,710	48,860	58	3,342							
Total:												
1896	1,408				4,651							
1897	4,242		417,043		21,838							
1898	5,000				10,000							
1900	7,651		74,000		24,661							
1904	19		56,739		415	1		7				
1905	3,389		70,386		200	2		2				
1906	1,864	53,206	260,004	111	22,226	3		13		6		1
1907	8,366	30,660	1,584,119	1,287	25,720	9	1,200	8	1,100			1
1908	3,628	1,383	568,548	61	18,255	4	620	8	1,220			3
1909	3,262	6,547	1,431,365	855	10,952	1	150	10	1,920			1
1910	14,172	30,461	1,235,448	191	10,153	2	200	13	2,305			1
1911	7,328	63,916	2,418,396	284	29,416	3	420	13	2,285			4
1912	25,418	130,402	1,484,851	572	46,490	8	970	25	5,970			9
1913	3,372	33,982	1,424,719	201	16,905	3	450	17	3,600			6
1914	5,389	88,385	820,378	64	43,055	3	450	27	5,200			8
1915	6,689	81,370	1,928,477	177	38,966			28	5,560			8
1916	9,312	41,344	1,327,934	528	30,558			32	6,929			12
1917	9,522	91,306	1,063,950	1,069	20,682			26	5,540			6
1918	6,247	131,250	788,060	616	23,537	11	1,180	24	4,595			5
1919	13,928	58,571	653,853	5,015	58,697	10	860	24	5,625			6
1920	9,102	125,998	317,987	578	31,121	2	60	26	4,490			14
1921	3,216	7,868	217,925	6	6,512	2	120	8	2,075			
1922	11,838	39,720	769,655	555	20,188			24	4,195			5
1923	18,713	35,633	1,476,230	112	44,037			25	4,440			8
1924	14,618	108,196	709,552	291	33,925	1	150	39	7,455			9
1925	15,953	120,305	1,387,240	450	24,895			28	5,546			18
1926	6,561	40,568	487,877	262	39,612			38	7,295			19
1927	5,291	27,389	230,852	494	13,508			11	1,790			18
By lines (included in above):												
1913				170								
1918				400								
1919	257			4,811								

NOTE.—No catch was reported in the years not shown in any division of this table.

Table 24 gives the catch by localities from 1896 to 1927, a broken record for the earlier years, but the most complete statement that could be prepared at this time. in a few instances it was advisable to make rather arbitrary divisions of catches where two or more places were joined as a single locality and where somewhat general terms

were used such as "Wrangell and vicinity." As the industry became stabilized and the requirements of law in such matters became better known and understood, these faults were in large part corrected. Not all of them disappeared, however, as even down to the present time errors of this kind persist. In other cases much of the purse seining in later years was done in the wider waters of the district, such as Ernest Sound and Bradfield Canal, and it was therefore impracticable to make more exact allocation of these catches. It was also deemed proper to combine the insignificant catches at Ham Island with those from Blake Channel, those from Bradfield Canal-Aere Creek with Bradfield Canal, those from Snake Bay with Snake Creek, and those from Bear Creek with Union Bay fish. The unallocated catches of the district comprise all salmon reported from Ernest Sound and several small catches from the following localities: Midway Bay, Boulder Cove, Alelof Bay, Buster Bay, Ham and Deer Islands, Smiths Bay, Jobs Inlet, Smoky Bay, Bobs Cove, Winchester Bay, Pats Creek, Thenis Bay, Emerald Island, Campbell River, Ulaf Bay, Ole Bay, Fogus Bay, Clay Creek, Sanco Bay, Canadastee, and Andrews Creek.

The table lists 36 localities as productive fishing areas of the Ernest Sound district. A few places may be regarded as unimportant, although they may have some value in showing that there are certain localities which have produced only limited numbers of salmon; yet others were trap locations which were occupied but a few seasons and then abandoned as being outside the migration route of the incoming salmon. In some cases the data were limited to catches in 2 or 3 years, covering localities whose importance as productive centers can only be determined by subsequent events. For that reason these catches have been kept separate.

Among the more important streams the most outstanding is Anan Creek, which in all probability produces a large percentage of the pink-salmon catch in the entire district. Anan is famed in the annals of Alaskan salmon lore and occupies a position in southeastern Alaska similar to that of Karluk River in the whole of Alaska. The data in table 24 show no exceptional returns from Anan, but when one includes the catches from Point Warde and from Bradfield Canal, a large proportion of which belonged to the Anan runs, the figures become impressive. Even then the real magnitude of these runs is not comprehended without making some allowance for the number of Anan salmon that are captured by fishing appliances along the shore of Cleveland Peninsula between Union Bay and Point Warde. Anan Creek is not a large stream, being much smaller than several other tributaries of Bradfield Canal and Blake Channel, but what it lacks in size is more than offset by other features, such as exceptionally fine areas for spawning fish, thus giving it unusual prominence as a salmon stream. Due to the ease of fishing at Anan Creek, the runs of salmon were relentlessly attacked. It became evident that the permanency of this valuable fishery might be jeopardized in a few years unless special protection were given to the runs of salmon. Accordingly an order was issued, effective January 1, 1913, closing Anan Creek, its lagoon, lakes, and tributary waters, together with the area within 500 yards of the mouth of the stream. On January 1, 1926, another order became effective, prohibiting fishing within 1 mile of the mouth of the creek, thus eliminating a trap which had stood for years close to the 500-yard line and obstructed the movement of fish into the stream. Since then no catches have been reported from Anan, but the Anan runs continue to make material contributions to the catches of the district through the operation of appliances in the lower waters of the sound.

Catch data for Anan show peculiar fluctuations, in that during the early history of fishing there the heavier runs came in the odd years, the peak being reached in 1909. Thereafter the catch declined progressively until 1914. It improved somewhat in the next 4 years, but dropped again in 1920 to the lowest figure in the history of the Anan fishery, which may have been due to a slackened fishing effort or to an actual scarcity of salmon. Following 1921, the catches improved in 1922 and 1923, but 2 years later the respective cycles were less than half as productive. This decline may be attributed in some degree to more stringent regulation of fishing, yet there still remains convincing evidence in these data that the runs had been reduced. How far the regulations now in effect may go toward restoring the runs to their former proportions cannot be foretold, although they have made possible an escapement of salmon probably sufficient to reestablish this fishery in a few years.

All species of salmon are caught at Anan Creek but no special significance attaches to any species except the pink salmon.

Anita Bay, Olive Cove, and Thoms Place, tributary to Zimovia Strait, are localities in which pink salmon chiefly are taken. The streams are small and empty into protected waters where fishing is subject to no interruption by storms or surf. Relaxation of fishing seldom occurs during the continuance of the runs in such places and in consequence overfishing often results. While the runs were never large at any of these places, there was a substantial decline in the catches during the last 10 years. This was more marked at Olive Cove and Thoms Place than at Anita Bay. The closing order of June 21, 1924, stopped fishing in all three localities, although the data for Olive Cove indicate that the order was disregarded in 1925. The stream at Thoms Place was estimated by Moser to be capable of producing 20,000 red salmon and 5,000 cohos annually. It was fished as early as 1897 and for several years did produce approximately that number of reds, but since 1916 the catch has exceeded 10,000 only once, while the average yield for 9 years, 1916 to 1925, was less than 5,000. This stream produced slightly more than 40 percent of the total red-salmon catch in the Ernest Sound district from 1897 to 1924, the total for the period being 239,465 for the stream as compared with 588,509 for the district.

Several small bays, indenting the western shore of Cleveland Peninsula, support good runs of pink salmon and produce a few thousand chums, cohos, and reds, but in practically every case the catch data contain questionable items. Occasionally trap catches were reported from the bays, when in reality they came only from the vicinity of the bays. This situation is clearly indicated in the Emerald Bay data for 1925, if, indeed, the catch was not similarly affected in other years. Union Bay and Vixen Inlet data are likewise faulty in that they include salmon caught by traps at the entrance of the bays from the general runs of the sound. The southern shore of Union Bay was a favorable locality for trap fishing, due to the preference of the migrating salmon for that shore as they swing into Ernest Sound from Clarence Strait from both northerly and southerly directions. The eastern shore of Etolin Island is far less productive, having smaller streams and fewer bays, although Menefee Inlet, Southwest Cove, Canoe Passage, and Fools Inlet are fairly important localities. The data for these localities have peculiarities like those on the opposite side of the sound, a case in point being the catches reported from Menefee Inlet in 1920, particularly in the number of king salmon and red salmon alleged to have been taken there. These faults in data affect the individual localities but not the catches in the district as a whole.

The total catches in the Ernest Sound district are shown graphically in figure 46. It appears that the catch of red salmon has maintained a fairly even trend for approximately 20 years, omitting 1921 and 1927, years in which unusual conditions prevailed. Depletion in certain localities was offset by larger catches in other places so that the totals have not been appreciably changed. The catch of king salmon likewise shows little fluctuation, the large catch in 1919 coming mainly from trollers who ordinarily do not allocate their catches in detail but for some reason did so in that year.

Wide fluctuations mark the catches of chums and pinks and both show the exceptional drop in 1927 which has been frequently mentioned as general throughout southeastern Alaska. With respect to chums these variations do not appear to be particularly significant, as, since 1921, the maximum catches, at least, have been about the same as those preceding this period and the general average not much lower.

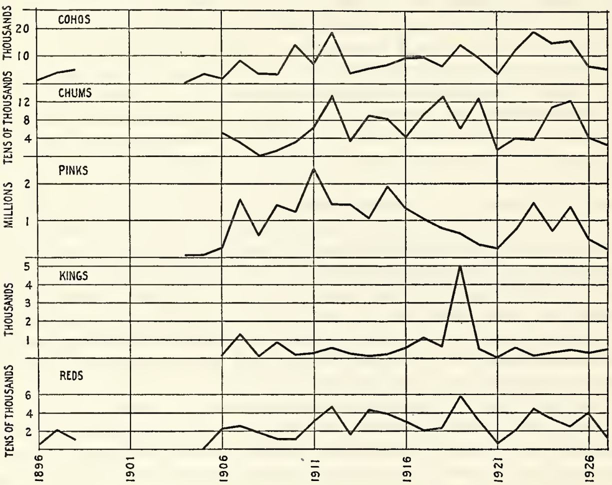

FIGURE 46.—Catch of salmon in the Ernest Sound district, 1896 to 1927.

The catches of pinks, however, maintained a noticeably lower level during the period 1922–27. Part of this doubtless can be accounted for as the result of the prohibition of fishing in some localities, but it is not all traceable to such causes; some reduction in abundance is quite clearly indicated.

The escapements into Anan Creek have been recorded by means of weir counts since 1925 and show marked reduction during the 3 years between 1925 and 1927. In 1925 the count of pink salmon through the weir in Anan Creek was 261,339 in 1926 it was 121,780; and in 1927 only 44,936. It is reasonable to assume that the situation at Anan was typical of conditions at other streams of the district, although probably less serious, for, as already indicated, Anan benefited from special protection which made possible a larger escapement of salmon into the stream than otherwise would have been the case. Less protection being accorded the other streams, the escapement, doubtless, was relatively smaller.

The condition of a fishery such as this is necessarily gaged primarily by the commercial catch of salmon and not by the number of fish that ascend the streams. If the catch remains fairly constant year after year without increased fishing effort, the fishery may be regarded as stable and balanced. An increased escapement without change in other conditions would mean larger runs, but when both the escapement and the catch decline steadily with an increased fishing effort there can be little doubt that the fishery is being depleted. That seems to have been the state of the Ernest Sound pink-salmon fishery at the end of 1927.

The catch of cohos in Ernest Sound shows, in general, a gradual increase throughout the period 1896–1927. The greatest recorded catch was made in 1912 but in spite of this and a very good catch in 1910 it is apparent that the trend has been upward and

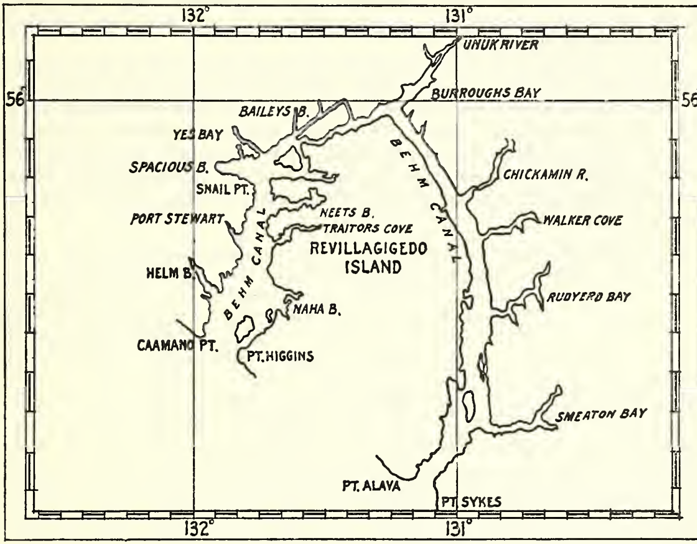

FIGURE 47.—Map of the Behm Canal district.

that the catches during the last decade herein considered have averaged well above those of the earlier years. This is due doubtless to the fact that the main run of cohos comes later in the season than the run of any other species so that, as the demand has increased, it has been easy to meet it by extending the period during which fishing is actively carried on.

BEHM CANAL DISTRICT

The Behm Canal district (see fig. 47) covers all the waters of the canal and its tributaries inside of a line across the northern entrance from Cape Caamano to Point Higgins and a line across the southern entrance from Point Alava to a point on the mainland shore 2 miles south of Point Sykes. The canal is a narrow body of water

separating Revillagigedo Island from the mainland and surrounding the island on all sides except the southwest coast between Point Higgins and Point Alava. It is divided naturally into two parts, eastern and western, the point of division being at the north end of Revillagigedo Island where the "canal" narrows to barely a half mile in width. At its northern extremity is Burroughs Bay into which empties the Unuk River, one of the larger streams of southeastern Alaska, southerly of which and 18 miles distant is the Chickamin River, a sizable stream also flowing from the mainland. Three narrow arms—Walker Cove, Rudyerd Bay, and Smeaton Bay—indent the mainland as tributaries of the eastern part of the canal. The eastern shore of Revillagigedo Island is very regular, being broken only by a few short bays. In contrast with this, the western shore of the island is marked by several conspicuous bays, and the shore of Cleveland Peninsula is similarly indented by bays of varying depth. Except as already noted, the streams of the district are small, yet several of them have been large producers of salmon.

Salmon canning in the Behm Canal district began about 1888 at three places—Burroughs Bay, Yes Bay, and Naha Bay—although fishing had been carried on at these localities for several years before the canneries were opened, the catches being prepared as pickled salmon. About 10 years later, fishing was extended to Helm Bay and Checats Cove where runs of red salmon were discovered. Throughout these early years of fishing the catches were largely unallocated. Allocated records became available for the first time in 1904 and the data compiled for that and subsequent years is fairly reliable.

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Anchor Pass:												
1917	8	5,933	5,383	11	38							
1918		14	1,008		1							
1924	7	111	8,633		161							
Ape Point:												
1926	98	436	25,127		340							
1927	116	1,048	6,523		201							
Bailey Bay:												
1907			2,000									
1908	42	20	7,728									
1910			6,212									
1911		295	12,901	4	177							
1918		80	1,008		1							
1922		26	4,265		2							
1925	364	4,013	19,189		1,414							
1926	118	485	3,375	1	274							
Bell Island:												
1914	93	502	637		333							
1919	1	174	890									
1920		2,750	1,844		4							
1922		52	2,811		58							
1923	3	1,083	12,020		87							
1924	1	2,102	2,096		8							
1925	52	456										
Betton Island:												
1919		731	290		3							
1925	1,008	7,548	151,841	2	1,894							
1927	237	667	5,802	13	821							
Bluff Point:												
1913	49	2,228										
1918	719	7,793	97,020	16	3,128							
1919	526	7,138	39,094	11	11,712							
1920	19	786	1,844	16	430							
1922	541	6,104	41,834	92	4,719							
1923	393	1,019	9,738	11	774							
Bond Bay:												
1922	395	3,477	28,801	8	185							
1923	111	41	7,582		117							
1924	2,556	4,667	90,492	2	4,748							
1925	2,680	11,502	167,375	144	4,057							
1926	2,181	7,223	145,037	3	2,949							
1927	676	2,061	11,005	39	1,782							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Burroughs Bay:												
1907	5,913				139							
1908	15,523	3,388										
1909	17,342	3,000										
1910	26,981	10,646										
1911	25,530	4,947	43									
1917	3	3,889	2,334		19							
1919	141	1,967	3,055	50	547							
1920	500	3,086	6,461		25							
1922	9	35	4,555									
1923		138	10,250									
1924	18	1,088	31,906		353							
Bushy Point:												
1913	109	2,472										
1918	56	2,182	47,215	15	63							
1920	8	2,338	2,266		62							
1924	7	256	7,808	1	254							
1926	341	2,574	61,614	5	1,963							
1927	358	2,466	8,267	31	2,094							
Cheeats Cove:												
1895					9,680							
1896					10,712							
1897	489	821	20,682		15,229							
1898	2,157		24,168		19,821							
1899	6,071		32,382		11,816							
1900	3,994		13,591		4,165							
1904			8,685		13,762							
1906			171		2,378							
1910			378		1,649							
1912	231	266	4,510		367							
1913					1,203							
1914	2	222	3,585		5							
1915		2	739		9,000							
1916	1,000				3,000							
1917		865	6,511									
1919		107	2,318		2,204							
1923	420	771	41,530		259							
1924	284	859	34,121	40	1,852							
1925	72	960	3,329	20	253							
1926	1	376	1,675		68							
Chickamin River:												
1904			5,510		5,008							
1907	7,709		150		563							
1908	10,804	1,484	20,469		274							
1909	13,000	2,000										
1910	18,989	3,193										
1911	12,130	999	7,017		729							
1912	10,924	472	105									
1914	122	7										
1915	50	3,992	198,679	21	318							
1916		3,149	20,600		176							
1917		5	1,025		1							
1918	1,584	51,514	280,044	230	1,210							
1919	3,587	30,670	64,810	900	2,762							
1920	484	17,414	72,158	355	1,401							
1922	1,927	3,636	50,162	4	230							
1923	415	12,220	102,239	223	799							
1924	13	3,697	25,446	25	108							
1925	40	1,789	54,135	6	97							
1926	6	1,233	8,264	13	102							
1927		71	2,542									
Chin Point:												
1926	206	516	20,860	3	818							
1927	105	557	4,724	4	1,857							
Clover Passage:												
1908			65,000									
1914	722	6,901	97,436		7,785							
1915	14	1,898	5,596		4							
1916	838	1,472	20,942	21	1,149							
1917	293	5,896	4,348		129							
1918	1,168	4,207	70,908		548							
1919		194	1,082		30							
1920	133	6,048	35,637	15	1,840							
1921	6		3,009		6							
1922	98	3,548	21,603		327							
1923	1,307	1,275	51,463		1,030							
1924	824	2,171	133,264		2,323							
1925	1,175	4,503	67,842	53	821							
1926	231	1,983	38,406	1	552							
1927	159	315	1,582	14	405							
Cow Creek:												
1908	13		330									
1911		15	6,279	2	2							
1912		691	4,845		92							
1915	4	316	9,832		24							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Cow Creek—Continued												
1919		78	194									
1920		448	2,720		12							
1922	128	2,450	49,761	18	50							
1923	12	3,243	10,015	21	17							
1924	8	257	13,164	2	26							
1925		117	4,227		6							
Deep Bay:												
1912			50,829		424							
1913	4	952	25,941		6							
1916	27	1,265	10,336		433							
1917	20	1,765	28,488		118							
1918	4	470	5,263									
1919	54	14,596	4,303		70							
1920		5	28		2							
1922	17	1	4,995		1,318							
1924	1	1,033	1,559		6							
Escape Point:												
1925		2	45		2							
1927	335	1,254	8,264	27	1,181							
Eva, Point:												
1926	41	746	11,902	19	355							
1927	14	355	336	18	40							
Fish Point:												
1924	7	103	12,260	13	39							
Fox Point:												
1925	1,696	10,100	94,319		1,890							
1926	413	5,130	34,802		969							
1927	164	1,610	7,628		858							
Francis, Point:												
1926	36	205	9,140		84							
1927	25	487	1,690		232							
Gedney Pass:												
1924	121	2,094	47,970	1	994							
1926	5	29	611		7							
Grant Island:												
1922	518	824	25,715		597							
1925	301	750	52,659		942							
1926	45	275	16,295	1	630							
1927			25		10							
Helm Bay:												
1896	1,931				6,681							
1897	700				6,000							
1906					1,177							
1907	424		61,530		4,136							
1908	958	7	17,993		2,621							
1909	5		20,105		60,041							
1910			782		4,488							
1911	2	83	29,094		3,520							
1912	2,758	1,535	59,734		1,312							
1913	10		1,109		315							
1914	5	13	1,296		84							
1915	21	20	34,381		466							
1916	7	34	3,046		21							
1917		17	7,485		25							
1918	4	29	13,251		5							
1919		204	6,438		529							
1920	10	243	8,973		149							
1922		282	2,737		50							
1923	126	671	13,460		276							
1924	442	3,286	65,181		1,718							
1925	83	698	36,447		443							
1926	324	1,488	63,307		1,324							
1927	531	2,025	25,400		3,262							
Herman Creek:												
1915	8	12,589	79,067		218							
1916		4,648	8,587		119							
1918	12	621	1,185		8							
1919	1	2,624	1,831	32								
1920		259	335		1							
1922	14	1,774	19,405	3	55							
1923	17	1,155	2,702	5	27							
Higgins, Point:												
1907	79	137	412,413		1,101							
1908	690	319	179,100		2,539							
1909	181	19,210	195,659		4,590							
1910	515	7,970	126,690		4,459							
1911	1,074	1,314	197,396		5,528							
1912			14,600									
1914	2	2,297	30,942		825							
1918		12	2,997		26							
1923	171	2,273	5,080		34							
1925	1,673	5,957	136,070	21	2,404							
1926	1,177	5,640	126,665	13	2,486							
1927	501	1,384	9,824	33	1,560							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Hot Springs Bay:												
1907			20,000									
1908	31	21	3,742		85							
1910			3,386									
1911		124	21,460	3	101							
1912	7	59	5,467									
1913			25,544		7							
1915	8	9,224	29,646		70							
1916		11	2,984		3							
1917	280	67	12,343									
1918	59	3,326	19,065		232							
1919	6	769	6,008		30							
1922	27	2,380	16,386	9	83							
1923	4	60	6,156		141							
1924	4	155	15,311		73							
Indian Point:												
1911	6,857	9,118	172,500		10,131							
1913	360	453	28,000		346							
1926	619	1,549	62,638	19	2,456							
1927	329	1,306	10,716	46	3,624							
Moser Bay:												
1907			39,105									
1908	1,272	1,508	33,153									
1910	1,667	6	57,534		15							
1912	3,046	1,617										
1913		87	602									
1918	2	951	648									
1922		1,609	415									
1923	2	142	2,883									
Naha Bay:												
1887					74,483							
1888					75,204							
1889					75,834							
1890	4,827				67,659							
1891	3,013				96,396							
1892	4,495				22,416							
1893					46,116							
1894					56,490							
1895			340,969		14,733							
1896			361,738		43,782							
1897			130,000		16,000							
1898	5,000		150,000		18,377							
1899	1,000		189,650		13,176							
1900	2,000		150,000		15,224							
1910	500	9,000	23,000		8,000							
1911	3,605				42,700							
1918	61	1,603	12,651	250	16							
1919	4	1,921	2,251		1							
1922		324	3,315									
1923	7	78	3,457		7							
Neets Bay:												
1910			7,955									
1911		132	19,482		459							
1912	4	269	16,257									
1913		1	1,300		2							
1918		393	51									
1922	3	583	1									
1923	43	94	8,583		168							
1924	377	7,077	81,233	1	2,613							
1925	65	594	15,738		194							
1926	28	77	2,351		31							
Nelson, Point:												
1923	449	1,136	1,383		41							
1924	46	862	1,728		27							
1926	189	2,800	22,417	53	1,372							
1927	37	777	2,381	37	525							
New Eddystone Island:												
1912	985	3,873	123,121	134	1,088							
1914		101	102	8	29							
1915	90	172	26,299		243							
1919	1,047	1,088	11,653	5	260							
1925	4	1,778	2,231		2							
Princess Bay:												
1917	581	155	5,035		13							
1919	22	297	3,034									
1920			68		2							
1922	90	99	13,095		9							
1923	104	1,042	16,913		315							
1926		486	778		5							
Pup Island:												
1913	184	3,600	93,255		344							
1914	609	16,047	42,725		4,932							
1915	1,554	13,984	225,188									
Raymond Cove:												
1918	21	2	1,382									
1926	171	918	21,134	2	386							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Roe Point:												
1909	3,134	17,524	151,042		1,368							
1910	11,147	31,061	250,331		41,110							
1911	65	502	194,849		7,836							
1918	235	703	34,852		136							
1919		20	1,534		37							
1922	90	99	13,095		9							
1923	2,447	8,585	111,928	198	2,848							
1924	1,439	16,444	73,547	23	6,063							
1925	1,396	18,292	120,650	172	2,416							
1926	1,672	16,445	193,365	235	8,734							
1927	228	6,214	18,612	99	1,870							
Rudyerd Bay:												
1913	364		327,720		2							
1914		5,600	20,500									
1915		5,229	98,755	1	10							
1916		7,000	12,000									
1917	1,289	493	5,009									
1918	2,632	5,806	26,714		14							
1919	457	8,427	13,895	4	670							
1920	12	4,123	34,055	26	186							
1922	868	12,246	147,179	13	356							
1923	1,578	17,478	152,288	55	1,993							
1924	42	7,300	41,943	9	386							
1925	12	1,036	2,781	4	92							
1926	311	763	1,486	51	182							
Sandy Beach:												
1913	101	3,621	578,995		22,147							
1918	776	4,934	110,825	25	4,589							
1919	390	7,000	42,443		8,301							
1920	317	15,403	29,094	6	4,274							
1922		13	1,015		151							
1923	756	1,784	42,803		1,839							
1924	695	3,532	43,391	1	2,698							
1925	174	1,159	4,709		328							
1926	36	118	575	1	91							
Short Bay:												
1907			135,000									
1908	169	1,224	82,338									
1909		2,500	33,000									
1910		2,391	48,910									
1911	23	1,289	30,792		41							
1912	5	735	41,117		35							
1913		1,693	24,148									
1914	33	5,435	8,443		10							
1915	614	3,215	54,161		22							
1916		1,786	4,959		9							
1917	104	902	3,563									
1918	510	5,156	104,783	1	171							
1919	3	1,374	5,976		449							
1920		852	2,318		59							
1922	730	1,625	21,819		169							
1923	12	3,185	17,203		197							
1924	22	2,529	37,032	1	310							
1925	3	1,057	4,015		14							
Shrimp Bay:												
1907			20,000									
1908	31	158	5,726									
1911		301	16,500		107							
1912		277	28,349		90							
1913			990									
1918		24	166									
1922	3	716	2,075		10							
1923		456	7,805		116							
1924	21	146	8,965		3							
Smeaton Bay:												
1904	353		9,439									
1907			1,579		1,112							
1910	35		1,308									
1911		850	23,548		28							
1912	3,664	7,932	213,064		5,841							
1913	28	1,460	1,277,613		607							
1914		20,577	35,895		308							
1915	1,923	43,378	423,206	188	2,999							
1916	1,000	50,657	26,267	3								
1917	5,376	63,319	114,196	73	1,411							
1918	109	10,618	137,674	10	1,756							
1919	758	42,927	87,823	98	3,252							
1920	68	16,739	58,786	17	969							
1922	4,457	137,517	445,763	79	3,582							
1923	6,987	109,751	624,680	126	9,019							
1924	3,059	197,451	536,086	241	9,456							
1925	1,901	117,526	384,851	404	5,368							
1926	1,665	23,200	75,591	227	2,842							
1927	16	435	5,558	127	115							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Smugglers Cove:												
1912	26	30	8,984									
1917	4,961	4,039	100,175	71	4,120							
1918	211	65	3,917									
1924	271	2,432	14,165	3	1,328							
1925	33	1,385	8,996		164							
1926	267	1,294	45,907	2	785							
1927	64	224	2,114		282							
Snail Point:												
1907			25,000									
1908	163	260	31,072		855							
1910	2,385	15,501	83,050		2,453							
1915			580		2							
1924		77	1,008		561							
1925	75	1,473	3,757	2	126							
1926	369	1,199	11,758	1	583							
1927	52	141	90	15	154							
Spacious Bay:												
1907			10,570									
1908	101	143	4,865		2,042							
1909	1,038	1,256	59,052		10,334							
1910	980	1,067			7,272							
1911	10,180	4,008	144,040		46,906							
1912	1,930	2,508	90,126		5,148							
1913	12		2,774									
1914		107	1,601		69							
1915		17	7,324		81							
1916		554	8,719		3,853							
1918	251	447	27,461		270							
1919	9	1,936	13,909	3	7,241							
1920			35		401							
1922	29	130	24,778		555							
1923	18	585	26,586		1,131							
1924	132	4,744	43,433	1	8,690							
1925	8	579	23,344		1,011							
1926	42	704	18,606		5,121							
1927	13	159	700	1	1,294							
Stewart, Port:												
1908	80	577	25,315									
1911		120	11,771		53							
1912	244	54	13,224									
1915		177	8,822		9							
1918	108	89	5,960		45							
1920	2	293	2,252		25							
1923		169	6,720		5							
1924	20	3,462	31,239		128							
1925		97	3,460		112							
1926		259	407		11							
Survey Point:												
1911	5,193	7,691	380,214		15,482							
1912	4,064	5,685	353,783		7,224							
1913	756	560	224,500		2,340							
1914	1,799	15,104	220,058		19,628							
1915	1,255	6,941	243,543		5,900							
1916	460	1,330	15,990		2,188							
1917	2,000	9,000	70,000		10,896							
1918	205	404	13,424		249							
1919	1,110	3,337	30,821		3,888							
1920	576	1,955	19,686		2,118							
1922	907	1,595	53,790		1,218							
1926	590	1,233	96,895	6	1,612							
1927	247	1,046	6,660	5	652							
Syble Point:												
1918	1,198	4,811	110,658	13	3,297							
1919	339	4,282	25,421	3	9,900							
1920	397	17,700	34,959	17	5,604							
1922	962	8,553	80,021	41	5,525							
1923	272	1,080	7,485	12	365							
1924	83	354	4,818		114							
1927	578	402	6,048	5	1,651							
Sykes, Point:												
1916	1,230	240	2,600		496							
1918	122	492	31,553		160							
1919	1,100	6,522	40,990	900	2,960							
1920	2,928	29,676	125,407	1,984	12,799							
1921	14,180	45,894	524,952	1,416	5,152							
1922	6,191	18,984	520,321	32	9,275							
1923	22,393	61,750	493,171	803	18,038							
1924	3,926	106,099	236,616	2,150	11,066							
1925	5,015	65,974	234,926	907	7,860							
1926	1,439	18,371	149,176	357	8,998							
1927	621	7,243	22,294	116	5,436							
Tatoosh Point:												
1926	8	34	1,119		14							
1927	22	58	422	2	59							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Tatoosh Rocks:												
1923	165	189	9,475	5	241							
1925	367	1,581	13,630	31	463							
1926	973	1,970	188,550		4,046							
1927	318	871	7,677	9	1,106							
Traitors Cove:												
1907			26,000									
1908	196	9,614	126,873		116							
1909		16,000	49,000									
1910	55	9,174	85,534		2							
1911		3,633	16,123		59							
1912	66	11,056	196,916		147							
1913		2,242	19,112		1							
1914	6	25,402	12,254		62							
1915	1	7,779	18,907		42							
1916	68	8,267	22,550		419							
1917	330	12,376	17,833		110							
1918	797	14,741	100,927		823							
1919	49	37,895	54,107		856							
1920	220	64,852	37,489	3	1,594							
1922	545	17,248	101,086		158							
1923	1,379	12,360	123,106	2	2,208							
1924	458	23,106	169,344	1	3,333							
1925	247	7,161	99,626		1,688							
1926	621	6,329	52,741	3	2,009							
1927	124	7,498	3,090	13	1,516							
Trollop, Point:												
1910	411	230	32,591	4	300							
1927	58	2,329	3,463	94	592							
Trunk Island:												
1911	57	340	15,726		240							
1924		18	209		8							
1925	262	753	49,864		455							
1926	90	248	11,579	2	109							
Unuk River:												
1910	9,000	5,081	21,218									
1911	7,645	66	2,085									
1912	26,768	8,977	11,858	44	212							
1913	686	3,516										
1914	3,303	1,914			2							
1915	2,915	2,945	3,281		160							
1916	330	8,762	2,338	13	78							
1917	3,853	8,097	10,749		77							
1918	7,515	6,086	14,288	4	36							
1919	1,991	9,169	427	30	393							
1920	102	1,918	10,437		56							
1922	2,066	2,273										
1923		22	530	1								
1924	826	209										
1926	1,369	1,033	689	12	6							
1927	2	1,345	6,947	24	55							
Walker Cove:												
1914	9	3,997	38,403									
1915		3,500	60,000									
1916		5,509	10,173									
1917	921	5,139	3		525							
1919	788	12,053	11,216	5	683							
1920	102	12,057	42,056	69	1,323							
1922	245	6,682	5,825		4							
1923	184	10,865	15,013	21	158							
1924		121										
Wasp Point:												
1926	445	6,064	47,112	24	1,079							
1927	88	2,717	7,695	34	917							
Winstanley Island:												
1910	320	83	8,950	146	276							
1925	131	1,327	5,559	2	321							
Yes Bay:												
1893					26,292							
1894					21,541							
1895					42,007							
1896					46,706							
1897	9,511	5,862	185,608		60,900							
1898	6,413		45,000		44,271							
1899	6,300	500	75,000		69,000							
1900	7,700	2,250	60,000		80,000							
1904			16,768		19,679							
1906	1,500				18,000							
1907		352	95,579		31,599							
1908	2,163	871	39,451		47,233							
1909	45	537	56,124		85,598							
1910	1,366	6,430	155,991		139,143							
1911	33	5,850	155,974	61	81,750							
1912		227	8,630		1,014							

TABLE 25.—*Salmon caught and fishing appliances used in the Behm Canal district, 1887–1927*—Con.

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps number
						Number	Number	Number	Fathoms	Number	Fathoms	
Yes Bay—Continued												
1913	22	514	42,991		337							
1914	55	547	479		17							
1918	1	177	5,237		11							
1919		256	921		283							
1922					2,526							
1923	2	20	906		72							
1924	2	95	4,227		589							
1925	50	1,506	8,813		61							
1926	175	154	506	6	205							
Unallocated:												
1904	27,690	10,184	367,323		157,697							
1905	7,147		217,551		151,389							
1906	15,556	20,540	321,123		103,093							
1907			75,000									
1908		137	2,203		610							
1909		8,499	88,000	120	12,070							
1910	290	222	10,493		61							
1911	5,655	7,369	397,725	50	19,792							
1912	8,026	32,881	1,027,092	201	70,331							
1913	2,018	12,178	593,695	52	4,696							
1914	1,997	142,595	284,635	234	20,429							
1915	9,438	63,152	1,086,333	484	31,017							
1916	7,322	60,177	254,915	718	17,608							
1917	17,775	128,995	534,463	1,222	18,530							
1918	22,677	128,334	1,467,752	1,593	20,546							
1919	68	19,874	61,424	7	1,539							
1920	1,259	60,031	175,010	168	5,301							
1921	16,319	7,600	71,470		1,253							
1922	974	10,795	162,647	6	2,606							
1923	369	16,178	109,412	28	6,391							
1924	632	13,051	118,490	1	2,001							
1925	421	6,829	17,832	83	461							
1926	3,228	11,932	185,722	102	5,835							
1927	794	7,048	30,436	227	14,148							
Total:												
1887					74,483							
1888					75,204							
1889					75,834							
1890	4,827				67,659							
1891	3,013				96,396							
1892	4,495				22,416							
1893					72,408							
1894					78,031							
1895			340,969		66,420							
1896	1,931		361,738		107,881							
1897	10,700	6,683	336,290		98,129							
1898	13,570		219,168		82,469							
1899	13,371	500	297,032		93,992							
1900	13,694	2,250	223,591		99,389							
1904	28,043	10,184	407,725		196,146	5		15		10		2
1905	7,147		217,551		151,389	2		9		1		1
1906	17,056	20,540	321,294		124,648	3		14		1		1
1907	14,125	489	923,926		38,650	2	300	14	2,940	3	250	2
1908	32,236	19,731	645,358		56,375	1	150	12	2,350			3
1909	34,745	70,526	651,982	120	174,001			13	2,560			6
1910	74,641	102,055	924,313	150	209,228			18	4,040	4	900	5
1911	78,049	49,046	1,855,520	120	235,641	1	300	15	3,330	6	300	6
1912	62,748	79,144	2,272,611	379	93,325			19	4,825			14
1913	4,703	35,577	3,268,289	52	32,353			20	4,150			11
1914	8,757	247,368	798,991	242	54,518			22	5,100			14
1915	17,895	178,530	2,614,339	694	50,585			30	5,930			13
1916	12,282	154,861	427,006	755	29,552			18	4,205			11
1917	37,794	250,952	928,943	1,377	36,012			34	7,290	3	500	15
1918	41,037	256,084	2,749,887	2,157	37,341			55	12,115	3	600	19
1919	12,451	217,630	538,158	2,048	58,600			42	8,380	5	1,200	9
1920	7,137	258,976	703,918	2,676	38,637			29	6,331			19
1921	30,505	53,494	599,431	1,416	6,411			1	150			2
1922	21,834	245,680	1,869,680	305	33,827			47	9,550			7
1923	40,146	270,898	2,054,565	1,511	48,713			71	14,575			13
1924	16,344	410,988	1,936,685	2,516	62,037			58	11,690			16
1925	19,308	278,502	1,792,260	1,851	35,359			42	8,680			29
1926	19,530	125,519	1,758,182	1,162	59,433			51	10,720			44
1927	6,812	54,113	228,515	1,033	48,299			7	1,450			43

NOTE.—No catches were reported in the years not shown in any division of this table. Included in this table are 50 king salmon in 1913 and 250 in 1918 that were taken by trollers.

Table 25 shows the catch of salmon in the Behm Canal district. It lists the recorded catches from 58 localities besides a large unallocated catch comprising data from 23 additional localities which were not of sufficient importance to be shown separately and all salmon which were reported merely from Behm Canal. Parts of the catches reported from Loring and vicinity in 1904, 1905, and 1906 are also included in the unallocated section. The minor localities were as follows: Blind Pass, Brow Point, Brownly Bay, Cove Inlet, Claude Point, Cove Point, Hassler Pass, Herman Bay, Humpback Bay, Humpback Creek, Hump Bay, Hump Creek, Ice Point, Neah Bay, Point Whaley, Saks Cove, Salt Lake, Shoalwater Pass, Swedish Meadows, Trunk Creek, Wadding Cove, White Point, and Wold Creek.

Several combinations of catches were made where names were apparently incorrectly spelled. Thus it was assumed that "Cheater Cove" was intended for Checats Cove; "Rodrick Bay," "Rogers Bay," and "Rudgers Bay" were meant for Rudyerd Bay; "Traders Cove" for Traitors Cove; "Mesh Bay" and "Meash Bay" for Neets Bay; Clover Passage and Hump Island catches were combined under the name of the Clover Passage; Smeaton Bay catches include part of the fish reported from "Smeaton Bay and Checats Cove," from "Smeaton Bay, Boca de Quadra, and George Inlet," and all salmon from Wilson Arm. Bell Island catches include small lots of salmon reported from Behm Narrows and Bell Arm.

The Behm Canal fisheries were first exploited at those streams which supplied red salmon, Naha Bay, Yes Bay, and Checats Cove being the more important. At this time practically all fishing was carried on by means of seines operated near the mouths of the streams. With the introduction of traps much of the fishing was transferred to the open waters of the canal at points where the fish passed close to the shore in their migration to the streams. As the number of traps increased the catches in the canal proper became larger and finally exceeded those from the bays.

Salmon enter Behm Canal through both entrances. Those using the northern entrance probably approach it chiefly from the south through Clarence Strait; those coming to the eastern part of the canal pass through the southern entrance from Revillagigedo Channel. Available information shows that the Behm Canal runs come mainly from southern waters. The tagging experiments in Sumner Strait in 1924 and subsequent years disclosed that some salmon came to the canal from the northwest through Sumner and Clarence Straits, but the movement from that direction was far less significant than that from the south as shown by the results of tagging on the west coast of Gravina Island, at Cape Fox, and at Cape Chacon. After the runs enter the canal there is probably little or no mingling of those using the northern entrance with those coming through the southern entrance. Trap fishing is concentrated at both entrances and the largest catches are made in these sections of the canal.

In the first 8 years of salmon fishing in this district only red and coho salmon were utilized; chiefly reds, as cohos were reported in 3 years only. Pink salmon were canned first in 1895, and since then have formed the principal product of this region. Two years later a catch of chums was reported, but this species was unimportant until after 1908. King salmon were taken at Burroughs Bay and other parts of Behm Canal long before catches were recorded, although the data here considered indicate that none was caught until 1909.

The omissions of the earlier years and the incorrect allocation of catches in later years have made it impossible to show with much accuracy the total production of this

district. In many cases fish from the canal were reported in combination with catches from Clarence Strait and other adjacent waters, and for that reason had to be treated generally as unallocated catches from southeastern Alaska. The catches in the several listed localities in the district are also confused and incomplete, which accounts for the large totals in the section of the table showing unallocated catches. Again, there are lapses in the records for almost every locality that was fished before 1925, so that in general the records are incomplete. Discussion of the statistical data must be limited, therefore, to the total catch records in the district.

The fishery regulations have restricted the field of operations in certain localities and prohibited fishing entirely, except by trolling, for definite periods. On February 1, 1906, Yes Bay reservation was created by an Executive order which closed the bay to all commercial fishing for salmon. On June 21, 1924, Yes Bay was protected further by the prohibition of fishing within 1,000 yards of Bluff Point and Syble Point at the entrance of the bay. On January 1, 1913, Naha Bay and its tributary waters were closed inside of a line from Loring Point to House Point. The entire bay was closed by the order of June 21, 1924. Walker Cove was also closed at the same time. By progressive steps, the general regulations effective each year from January 1, 1919, to June 21, 1924, closed all streams in southeastern Alaska and prohibited fishing by any means within 500 yards of the mouths of the streams. These regulations were superseded by the law of June 6, 1924, and the regulations laid down under the authority of that act of Congress. The important change thus made provided for a closed season of 20 days from August 20 to September 9 in certain waters south of the fifty-seventh parallel of north latitude, of which Behm Canal was a part. A slight modification in the date of the midseason closed period was made in the regulations which were effective after 1924, but other restrictions were added limiting the size of nets, extending the distance interval between traps, suspending all fishing, except trolling, after October 15, closing Wilson and Bakewell Arms of Smeaton Bay, part of the north arm of Rudyerd Bay, the estuary at the mouth of Chickamin River, Shrimp Bay, Traitors Cove Lagoon, and opening Naha Bay west of the longitude of Cod Point, but continuing the closure of Long Arm and Moser Bay, which were covered by the original Naha Bay closing order. The enforcement of these regulations reduced the catches in these designated waters very perceptibly, but apparently it had little effect upon the total catch in the district, as an increase in the number of traps from 16 to 44 in 2 years was sufficient to maintain the level of production.

All species of salmon were taken in Behm Canal and the catches are shown graphically in figure 48. Reds came chiefly from Naha and Yes Bays, but smaller catches were made at Checats Cove, Helm Bay, Spacious Bay, Traitors Cove, and Smeaton Bay, while unimportant catches were reported from many other localities. Exceptional catches were made in a few years due, apparently, to better than average runs at Yes Bay. After the closing of Yes and Naha Bays to insure an escapement of salmon for artificial propagation at the fish-cultural stations located on lakes tributary to these waters, a marked reduction in catch occurred. The largest catches were made between 1904 and 1912; previous to 1900 the catches had been fair, averaging about 80,000 each year. Since 1912 the average catch has been much lower, approximately 50,000, and shows no marked change between 1913 and 1927.

No large catches of king salmon have ever been definitely allocated to Behm Canal. The best catches of this species were made by traps near Point Sykes at the southern entrance. Stragglers were taken at several localities, but no distinct run was evident

except at Smeaton Bay. Trollers probably made considerable catches in the canal but failed to allocate their catches. Inasmuch as king salmon are found on the feeding grounds, often far from the streams they will eventually ascend to spawn, the lack of complete catch records for a given district is not a serious matter, as the presence of kings in many localities does not constitute a run in the sense that they are approaching a definite stream. Often the schools are composed of salmon of different ages and from several runs, so that catches of king salmon in Behm Canal do not necessarily mean that they were exclusively Behm Canal fish. This condition exists in respect of kings perhaps more than to any other species, and the fluctuations in catches are meaningless in determining the increase or decrease of runs in all such places.

FIGURE 48.—Catch of salmon in the Behm Canal district, 1887-1927.

The pink salmon fisheries have yielded fairly large catches in some years and extremely poor ones in other years, but without the definite recurring biennial variations which were observed in some other districts. From 1922 to 1926, a period of 5 years, catches were fairly uniform, but 1927 shows the smallest return the district had known in 20 years, indicating beyond question a real scarcity of pink salmon. The total catch was only 228,515, notwithstanding that 43 traps were located in the canal that season. With this exception, the fishery has shown no evidence of decline in recent years and appears in fact to be even more productive, although the regulation of fishing in this period was more drastic than ever before.

The chum fishery produces annually a few hundred thousand salmon. Since 1913 the trend has been almost level except as it dropped in 1921 and 1927 on account of conditions which have been repeatedly mentioned.

Cohos have been reported from Behm Canal since 1895. The catch is marked by wide fluctuations, the high peaks occurring in 1911, 1918, and 1923, and the low points in 1905, 1913, 1920, and 1927. The real condition of this fishery, however, is not shown in the data presented, as no doubt exists that many cohos were taken in Behm Canal by trollers who made no allocations of their catches.

As measured by these incomplete data, the fisheries of Behm Canal show no material decline in production during a long period. Certain localities undoubtedly

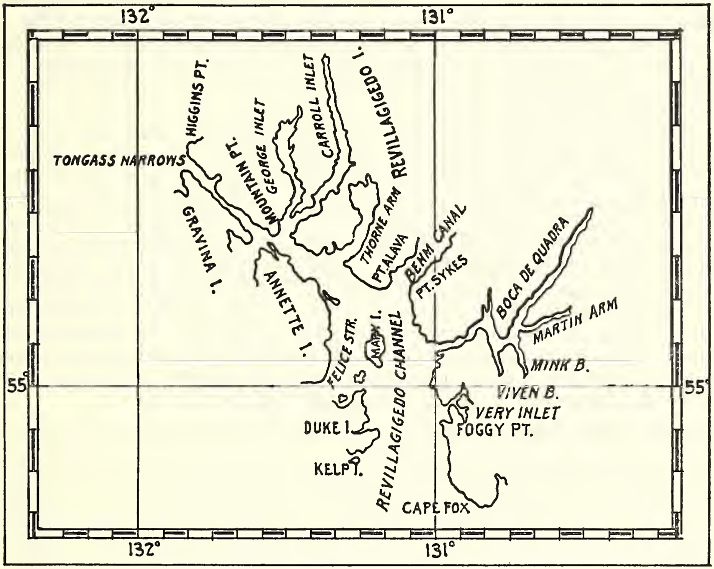

FIGURE 49.—Map of the Revillagigedo Channel district.

have been depleted to some degree, but the development of fisheries in new places has counterbalanced these losses and maintained the yield at a fairly constant level.

REVILLAGIGEDO CHANNEL DISTRICT

This district covers all waters southerly and easterly of a line from Point Higgins to Vallenar Point at the northern end of Gravina Island to the international boundary in Dixon Entrance exclusive of any part of Nichols Passage southwesterly of a line from Gravina Point to Walden Point and any part of Felice Strait westerly of a line from Annette Island to Duke Island along a meridian at 131°28′ W. longitude, and all waters west of a true north and south line from Cape Northumberland on Duke

Island to the southern limit of the district. A line due south from Cape Fox forms the eastern boundary of the district in Dixon Entrance. The eastern boundary at the southern entrance to Behm Canal is defined by a line from Point Alava to a point on the mainland shore 2 miles south of Point Sykes. It is a small district, barely 62 miles in length, and in the main embraces the waters of Tongass Narrows, Felice Strait, and Revillagigedo Channel and their tributary bays and streams. (See fig. 49.)

Four rather long bays or inlets indent the eastern shore of the district, while numerous smaller bodies of water break the shores of Annette and Duke Islands, all of which contain the outlets of salmon streams.

The earliest recorded catches of salmon in this district were made at Kah Shakes Cove and George Inlet in 1892. In the next 3 years fisheries were opened, in the order named, at Annette Island, Ketchikan Creek, and Boca de Quadra, and in 1897 at Ward Cove. Apparently no other localities were fished until after 1900. No stream statistics are available for the years 1901 to 1903, inclusive, but it is probable that most of the localities listed for the first time in 1904 were fished during the 3 years for which data could not be obtained.

The first cannery in this district was located on Boca de Quadra in 1883, where it was operated until 1886. It was then moved to Ketchikan and continued to pack salmon until 1889, when it burned. In 1896, another cannery was opened on Mink Arm of Boca de Quadra, and is still in existence. The third cannery was located at Ketchikan in 1900, and it likewise is still in operation. From 1889 to 1902, three salteries were opened on Boca de Quadra and operated for varying lengths of time. One was also built on Tongass Narrows in 1902, but was operated only during that season. This constitutes the early history of the salmon industry in this district as far as it concerns the plants within the district, although canneries in adjacent districts took salmon from these waters. From this beginning, the salmon-canning business grew rapidly and in a few years made Ketchikan the most important fishery point in Alaska, there being a concentration of canneries, salteries, and freezing plants at this port, which later developed a large export trade in fresh fish.

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Alava, Point:												
1912	4,000	2,000	120,000		4,000							
1916	1,026	7,422	53,056		2,941							
1917	6,708	37,295	229,414		3,041							
1918	1,456	2,877	95,550		1,761							
1919	728	2,111	38,911		4,719							
1920	1,063	6,047	46,096		3,214							
1922	5,089	14,295	223,238		6,639							
1923	38	24	659		18							
1924	796	12,742	41,674	7	1,101							
1925	1,035	11,736	78,235		1,590							
1926	1,269	10,056	130,860	116	3,435							
1927	465	4,893	14,405	50	2,071							
Annette Bay:												
1911	2,814	8,171	22,314		271							
1912	1,182	6,380	73,220		5,945							
Annette Island:												
1893			140,000									
1896			68,000									
1897			29,000									
1911	1,898	3,515	20,348									
1922	417	315	18,681		255							
1923	2	1,443	187		2							
1924	47	28,455	2,828		21							

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Annette Point:												
1919		658	2,136		27							
1922	227	1,675	10,923		505							
1923	111	3,667	22,003		540							
1924	12	3,088	24,274		444							
1925	130	9,891	31,232		531							
1926	1,248	36,803	18,648		838							
Black Island:												
1912	5,048	4,078	73,892		4,572							
1913	697	203	270,605		2,804							
1914	1,535	8,388	109,059	35	3,933							
1915	9,835	36,844	566,926	14	25,727							
1916	1,182	15,500	50,818	138	5,704							
1917	5,512	41,000	145,297	90	6,200							
1918	3,318	29,847	279,372	81	8,052							
1919	2,577	41,803	129,519		10,612							
1922	8,894	15,006	231,850	91	7,533							
1923	4,281	10,607	185,258	2	6,040							
1924	4,412	57,166	153,852	182	7,800							
1925	789	8,956	55,683	209	2,461							
1926	159	1,047	10,956	15	636							
1927	68	997	873	2	105							
Boca de Quadra:												
1895					97,000							
1896					137,000							
1897					65,000							
1898	5,664		100,000		98,138							
1899	4,522		301,000		166,232							
1900			223,000		174,614							
1904			232,748		53,523							
1906			36,959		86,580							
1907	11,916	8,095	1,010,941		209,799							
1908	12,500	31,167	671,696		88,629							
1909	2,697	1,238	542,933		42,804							
1910	10,025	30,574	152,927		92,600							
1911	7,553	45,454	666,268		118,202							
1912	8,037	33,452	776,285		45,959							
1913	1,165	3,405	1,069,722		17,528							
1914	3,319	58,292	411,206		20,275							
1915	7,488	39,150	306,562		26,876							
1916	4,798	47,871	305,861		21,625							
1917	7,588	121,342	119,665	165	16,867							
1918	3,588	62,534	802,332	373	14,872							
1919	899	25,636	198,720	113	10,263							
1920	674	28,000	106,298	521	8,027							
1921		3	51,171		1,020							
1922	1,298	18,929	493,996	56	9,230							
1923	1,277	42,477	78,492	8	5,549							
1924	1,364	440,771	235,518	205	12,627							
1925	1,014	132,123	126,969	774	5,637							
1926	3,442	17,890	51,378	426	22,644							
1927	68	2,907	2,815	225	2,483							
Bold Island:												
1916	1,667	12,638	135,397		6,068							
1917	1,499	13,653	93,805		3,767							
1918	536	4,156	117,728		2,460							
1919	2,068	7,872	89,242		4,858							
1920	865	5,845	56,277		2,483							
1921	128	383	32,681		165							
1922	1,200	6,867	49,872	14	1,782							
1923	2,070	2,744	44,886	32	1,568							
1924	1,150	15,375	41,780		2,470							
1925	2,353	11,094	84,430	27	2,784							
1926	963	14,600	77,965	61	7,801							
1927	202	2,641	6,542	160	1,507							
Breakwater North:												
1925	1,567	4,529	42,306	10	3,736							
1926	843	2,659	60,758	12	4,798							
1927	279	1,840	7,839	20	1,064							
Breakwater South:												
1925	1,860	6,884	38,189	63	4,710							
1926	734	2,971	40,761	18	6,035							
1927	311	2,208	10,976	28	1,533							
Carroll Inlet:												
1904			15,150		456							
1907			675									
1908			251,360									
1910	124		48,979		311							
1911	3,024	642	124,327		1,240							
1913	85		43,313		129							
1914	150	17,792	90,799		821							
1915		74	3,474		10							
1916	44	11,863	38,030		167							
1917	767	25,444	104,653		2,534							

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Carroll Inlet—Continued.												
1918	433	10,426	57,358		832							
1919	1,154	41,019	47,721	10	892							
1920	225	47,747	49,052		1,340							
1921	38	2,018	27,815									
1922	555	47,136	99,915	8	456							
1923	3,148	28,321	178,567		4,510							
1924	306	77,835	79,843	23	3,393							
1925	447	36,629	51,709	35	907							
1926	435	15,436	86,440	10	1,385							
1927	125	363	1,985	10	372							
Coho Cove:												
1917	5,009	4,042	61,451		2							
1922	1,796	7,181	101,423		3,488							
1923	1,570	9,194	147,116		2,888							
Cone Point:												
1919	4,771	3,010	37,984		5,397							
1925	786	10,499	82,060		500							
1926	315	2,368	59,522		3,195							
1927	396	1,845	5,501		895							
Crab Bay:												
1922	3,335	35,159	144,675	33	4,246							
1923	3,580	51,642	214,516	71	7,531							
1924	1,164	25,015	150,462	13	3,644							
1925	864	25,056	98,762	19	2.435							
1926	1,835	19,606	129,740	70	5,601							
1927	205	1,622	8,656	39	1,409							
De Long Islands:												
1924	979	4,111	48,214		1,952							
1925	1,419	4,753	38,857	7	3,148							
1926	492	3,506	40,841	20	3,515							
1927	168	936	2,890	4	594							
Duke Island:												
1911			2,328		1,629							
1918	1,019	3,571	34,084		2,613							
1922	519	2,777	8,000	1	208							
1923	331	1,014	20,177		1,103							
1924	22,369	9,081	70,046	239	9,743							
1925	2,343	3,640	24,760	48	1,902							
1926	6,874	26,402	109,487	85	9,222							
1927	4,610	9,028	21,480	1,458	7,894							
Duke Point:												
1925	17,644	15,038	129,333	730	6,962							
1926	4,031	5,323	85,722		2,769							
Felice Strait:												
1913			7,412									
1916	294	378	16,535		1,686							
1917	2,000	5,006	11,660	10	2,528							
1918		21	3,519		68							
1920	139	451	2,444		51							
1922	5	1,136	227									
1924	39	41	4,512		11							
1926	223	1,670	9,757		318							
1927	62	169	446	130	93							
Flag Point:												
1926	6,752	2,591	32,861	76	3,923							
Foggy Bay:												
1904	3,920		1,766									
1908	1,190	3	27,205		366							
1910	1,697		12,858		676							
1911	1,037		9,979		236							
1913	60	3,602	35,849		15							
1915	425	6	36,910		576							
1916	300	117	14,753		610							
1917	435	34	570		243							
1918	157	18	30,262		49							
1919	346	2,551	81,552	19	6,076							
1922	2,594	3,084	144,783	1	2,250							
1923	225	139	17,391		599							
1924	6,137	38,915	280,718	1,159	20,370							
1925	687	2,504	40,981	1	2,209							
1926	5,477	35,461	373,100	1,676	30,082							
1927	4	118	439		206							
Foggy Point:												
1920	1,132	4,262	69,344	88	5,585							
1922	9,961	28,242	379,986	797	10,562							
1923	15,747	33,716	680,227	1,050	37,216							
1924	10,522	59,418	279,977	434	44,504							
1925	8,579	19,921	194,099	721	4,750							
1927	2,158	10,671	42,265	1,540	9,441							
George Inlet:												
1892			4,875		9,061							
1893			9,518		3,191							
1894	1,426		11,247		3,219							
1895	854		7,905		3,787							

Table 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
George Inlet—Continued												
1896	531		1,576		2,142							
1898					225							
1900	2,358		39,085		6,949							
1904	2,316		25,156		10,804							
1906	969	485	9,380		8,161							
1907	3,500		37,568		7,125							
1908					7,200							
1909			36		2,111							
1910	3,808	1,294	44,653		6,265							
1911	4,283	4,954	153,133		7,320							
1912	809	1,688	88,165		4,257							
1913	548		59,408		1,979							
1914	409	8,422	71,366		5,788							
1915	286	5,417	75,821		5,225							
1916	1,384	10,438	38,283		1,402							
1917	141	4,570	9,393		1,453							
1918	531	18,528	54,098	1	1,518							
1919	1,451	21,738	86,760	392	9,870							
1920	67	19,486	25,209		1,378							
1921	4	24	38,900		2,062							
1922	459	42,715	28,766		3,169							
1923	1,841	6,553	95,370	1	2,192							
1924	844	23,470	61,400	9	2,285							
1925	822	18,939	67,971	5	1,877							
1926	40	7,219	9,389		165							
1927	7	2	50	1	130							
Harbor Point:												
1923	454	3,510	49,834	7	879							
1926	98	869	11,220	2	303							
Hassler Harbor:												
1904	73		33,032		16							
1908	239	8,580	15,488									
1910		7,752	18,250									
1915		2,020										
1917	123	6,094	8,572		14							
1919	121	11,640	19,407		51							
1920	29	2,700	2,955		37							
1922	170	5,348	2,345		28							
1923	1,897	69,773	7,616		49							
1924	402	39,872	10,845	3	553							
1925	254	93,121	962		28							
1926	408	18,645	3,041		4							
Kah Shakes Cove:												
1892					9,218							
1893					14,399							
1894					10,579							
1895					16,181							
1897					8,000							
1898					14,100							
1899					15,000							
1900					15,600							
1906	200		4,865		5,791							
1907			6,833		4,152							
1908	420		11,672		7,688							
1909	660		10,500		5,033							
1910	871	1	9,917		7,552							
1911	1,978		31,676		7,909							
1912	6,093	9,538	269,569	14	15,170							
1913	849	3,578	272,470	8	3,950							
1914	1,318	3,111	77,833	45	2,671							
1915	2,311	5,613	127,843	173	3,396							
1917	2,000	5,000	25,000		3,121							
1919	9	67	2,835		27							
1920	3,826	28,792	213,859	312	22,356							
1922	6,865	9,126	137,514	98	6,216							
1924	4,355	52,088	223,935	99	18,371							
1925	1,408	7,679	56,313	39	3,374							
1926	3,679	15,448	169,820	364	14,293							
Kah Shakes Point:												
1911	3,332	4,721	107,309		13,500							
1913	440		207,365		3,026							
1923	4,067	15,663	140,044	52	6,769							
1927	49	1,528	2,590	65	1,010							
Kah Shakes Shore:												
1927	330	2,698	8,489	530	3,082							
Kelp Island:												
1924	7,274	535										
1926	358	1,796	9,488		238							
1927	1,470	2,780	5,836	662	3,078							
Ketchikan Creek:												
1894			500,000									
1895			246,000									
1896			300,000									
1897			500,000									
1904			39,763									

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Ketchikan Creek—Contd.												
1906	70	69	1,008									
1907			273,860									
1908			21,153									
1909			135,000									
1910	189		46,326									
1911	754	511	129,539		293							
1913			18,856		6							
1915	1	18	9,616		491							
1917			11,131		3							
1919	2	910	398		1							
1922	63	27	5,154		73							
Kirk Point:												
1912	14,786	7,120	287,834	115	9,206							
1914	361	4,677	25,389	77	3,847							
1916	1,328	3,593	27,112	420	4,028							
1917	1,325	7,387	27,825	31	1,877							
1918	2,637	3,612	81,575	5	1,271							
1919	2,156	5,655	35,847	17	5,373							
1920	1,478	6,511	39,900	70	3,888							
1922	1,858	4,086	82,990	220	4,101							
1923	4,909	10,055	121,336	174	4,905							
1924	949	18,505	45,939	109	7,637							
1925	900	6,004	37,308	13	2,206							
1926	1,210	7,355	72,132	176	6,732							
1927	306	3,112	8,003	377	2,488							
Kwain Bay:												
1923	135	52	2,590		18							
1926	263	1,754	29,690	2	605							
Lucky Cove:												
1910			11,319									
1915	463	2,031	62,885		923							
1916	205	669	45,233		630							
1917	925	10,470	125,580									
1918	3,032	5,992	198,998		3,680							
1919	1,716	2,292	74,120		3,891							
1920	956	5,582	42,089		2,636							
1922	5,447	11,577	123,532	123	6,266							
1923	3,929	16,205	285,500	12	5,876							
1924	1,348	15,060	42,750		2,200							
1925	4,467	28,431	171,304	45	7,072							
1926	1,580	8,695	87,008	22	4,956							
1927	244	2,687	9,819	2	1,350							
Marton Arm:												
1907		26										
1918	2,500											
1919		1,308	2,355	13	68							
1923	77	10,598	20,003	1	1,007							
1924	152	6,084	15,700		227							
1925	25	6,678	9,925	15	288							
1926	1	401	373		261							
1927		127	196	31	69							
Mary Island:												
1917	1,981	6,088	21,660		984							
1920	446	1,018	46,017	3	712							
1922	32	109	3,645		22							
1923	1,079	1,893	70,634		873							
1924	1,464	1,460	30,136		1,586							
1925	11	200	1,025		23							
1926	495	769	4,605		515							
Mink Bay:												
1919	36	125	26,965	1	264							
1920		79	475		39							
1922	45	13	3,197		2							
1923	766	894	1,582	1	1,067							
1924	13	5,314	12,716		327							
1925	45	14,047	12,699		408							
1926	19	3,020	17,937		1,715							
Mountain Point:												
1913	1,170	1,563	117,100		3,480							
1916	1,752	6,548	48,135	17	1,487							
1917	206	2,271	28,428		137							
1919	158	9,019	65,628	3	4,127							
1920	10	557	2,460		80							
1922	1,241	7,231	80,096	6	1,848							
1923	3,561	5,045	76,236	65	3,011							
1924	498	10,184	46,849	14	1,761							
1925	955	11,931	106,949	18	2,012							
1926	532	5,293	84,306	16	1,741							
1927	250	1,863	3,757	14	818							
Nadzaheen Cove:												
1904			33,834									
1905			26,110									
1906	74	3,898										
1907	701	5,960										

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Nadzaheen Cove—Contd.												
1908	75	3,369	3,813									
1909		605	2,292									
1910	23	618	26,113									
1911	2,631	7,558	31,569		6,260							
1912			1,414									
1913			2,800									
1924		143	1,056		15							
Orca Point:												
1919	4	274	2,819	1	264							
1927	114	504	2,087		618							
Slate Island:												
1911	8,421	12,402	489,656		31,427							
1912	2,248	6,428	292,890		12,142							
1913	300	260	388,096		5,003							
1914	1,861	14,436	108,253		6,786							
1916	886	16,554	135,111		6,949							
1917	9,230	64,485	246,028	223	12,449							
1918	5,185	18,770	462,314	93	12,085							
1919	4,184	23,474	170,487	30	15,229							
1920	1,882	32,451	101,368	109	7,395							
1922	9,309	36,764	572,409	128	12,559							
1923	8,824	35,571	377,649	147	11,990							
1924	5,694	118,379	152,938	119	12,083							
1925	3,958	41,417	192,879	94	6,680							
1926	4,494	27,504	196,209	342	18,466							
1927	999	9,068	32,749	640	6,419							
Thorne Arm:												
1906			839		504							
1910	128											
1913			43,127									
1914	142	7,522	18,284		5							
1915	110	189	39,624		141							
1916	10											
1917	2,124	4,578	64,222		2,577							
1918	1,395	4,315	105,777	5	1,001							
1919	468	5,667	26,326	1	1,792							
1920	851	10,644	26,223		205							
1921	1	1,826	9,722		1							
1922	241	6,506	22,478		94							
1923	1,912	22,649	161,384	6	1,882							
1924	570	11,407	143,636		1,667							
1925	1,207	23,486	129,844	19	1,456							
1926	1,714	23,640	136,595	30	2,378							
1927	124	1,277	5,376	52	409							
Tongass Narrows:												
1906		392	15,668									
1909	293	77	37,726		512							
1910			4,825									
1911	2,588	1,316	79,231		931							
1912	8,600	4,262	276,874	400	11,471							
1913	101	490	133,303		2,872							
1914	1,816	16,592	129,139		7,772							
1915	2,739	19,380	299,693		12,984							
1916	4,418	11,066	89,542		4,986							
1917	5,743	11,492	155,338	97	1,154							
1918	3,400	15,651	328,871	92	3,594							
1919	1,156	10,608	88,609	18	4,830							
1920	1,785	21,169	133,799		8,215							
1921	16	326	24,111									
1922	202	4,261	47,059		768							
1923	254	688	139,365	32	569							
1924	206	2,474	27,258	12	626							
1925	198	2,795	28,315	10	499							
1926	626	3,540	46,938	12	424							
1927	275	972	4,350	21	1,105							
Tree Point:												
1919	1,290	10,320	179,061		17,017							
1920	5,372	54,887	158,953	165	22,458							
1922	21,962	13,326	375,330		15,742							
1923	16,896	36,769	758,832	9	36,643							
1924	11,935	22,356	354,100		32,113							
1925	2,820	10,155	51,029	76	6,226							
1926	2,455	17,201	228,853	85	18,432							
1927	991	6,853	33,106	876	6,966							
Very Inlet:												
1918	129	836	87,123		154							
1919	147	66	23,332		135							
1920			2,195									
1922	168	2,106	23,509		176							
1923	596	5,991	47,881		575							
1924	12	984	4,361	1	438							

TABLE 26.—*Salmon caught and fishing appliances used in the Revillagigedo Channel district, 1892 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Ward Cove:												
1897	600		11,000		1,500							
1898	743		34,935		1,535							
1899	1,000		15,000		1,000							
1900	1,179		52,511		873							
1904			1,153		44							
1906	1,037	230	21,918		1,960							
1910	461	175	17,752		709							
1912	92	62	9,463		514							
1913			1,513									
1916	238	780	73		30							
1917	603	167	2,222		17							
1918	207	24	958		125							
1919	202	878	1,860		36							
1920		589	1,805		289							
1921					2							
1922	165	1,634	4,407		9							
1923	92	340	8,895		43							
1925	290	335	4,742		44							
1926	2	46	162		5							
1927	40											
Unallocated:												
1904	27,691	10,184	367,323		157,697							
1905	7,148		217,552		151,390							
1906	15,556	18,540	280,324		103,093							
1908				8,800								
1910	1,307	5,456	9,946									
1912	2,079	7,496	60,416		132							
1913	1,745	7,836	221,982	599	9,995							
1914	5,986	26,762	282,542	306	25,983							
1915	14,470	25,970	506,891	688	42,410							
1916	5,465	27,533	161,029	899	20,285							
1917	13,012	75,556	256,831	1,848	20,246							
1918	23,093	96,181	1,127,371	3,476	33,065							
1919	4,433	35,176	242,562	237	20,685							
1920	7,475	76,177	403,743	174	30,645							
1921	9,087	1,543	160,306		915							
1922	7,925	14,959	163,465	48	5,541							
1923	7,668			1,309								
1924	1,646	5,073	54,036	58	3,349							
1925	5,119	19,191	133,251	355	11,785							
1926	4,954	14,263	161,640	78	18,224							
1927	201	3,235	5,697	38	1,157							
Total:												
1892			4,875		18,279							
1893			149,518		17,590							
1894	1,426		511,247		13,798							
1895	854		253,905		116,968							
1896	531		369,576		139,142							
1897	600		540,000		74,500							
1898	6,407		134,935		113,998							
1899	5,522		316,000		182,232							
1900	3,537		314,596		198,036							
1904	34,000	10,184	749,925		222,540	7		13				
1905	7,148		243,662		151,390			1				
1906	17,906	23,614	370,961		206,089	3		14				
1907	16,117	14,081	1,329,877		221,076	3	385	22	4,175	2	675	2
1908	14,424	43,119	1,002,387	8,800	103,883	2	325	16	3,180			3
1909	3,650	1,920	728,487		50,460	1	175	8	1,620			1
1910	18,633	45,870	403,865		108,113	2	135	14	2,890	11	1,650	2
1911	40,313	89,244	1,867,677		189,218			18	3,910	3	150	3
1912	52,974	82,504	2,330,022	529	113,368	8	550	16	3,275	1	300	10
1913	7,160	20,937	2,892,921	607	50,787			24	4,925			6
1914	16,897	165,994	1,323,870	463	77,881			21	4,150			9
1915	38,128	136,712	2,036,245	875	118,759			19	3,675	3	300	12
1916	24,997	172,970	1,158,968	1,474	78,598			17	3,065			19
1917	66,931	445,974	1,748,745	2,464	79,214	2	200	40	7,950	2	400	23
1918	52,616	277,359	3,867,290	4,126	87,200	1	70	42	7,810			26
1919	30,076	263,877	1,675,156	855	126,504	5	350	45	8,365			23
1920	28,275	352,994	1,530,561	1,442	121,033			36	7,002	2	165	44
1921	9,274	6,123	344,706		4,165			8	925			5
1922	92,042	341,590	3,583,465	1,624	103,768			55	10,580			23
1923	91,337	427,237	3,951,230	2,979	145,912			63	12,585			31
1924	86,659	1,105,401	2,741,353	2,686	193,318			90	18,010			31
1925	63,996	587,662	2,122,121	3,333	88,240			63	12,585			36
1926	58,020	355,847	2,588,202	3,714	195,654			76	16,250	5	1,000	48
1927	14,521	76,944	249,217	6,975	58,366			18	3,736			46
By lines (included in above):												
1908				8,800								
1923	7,668			1,309								
1924	215			55								
1925	242			36								
1926				83								

NOTE.—No catches were reported in the years not shown in any division of this table.

Table 26 shows the number of salmon that was reported as caught in the Revillagigedo Channel district from 1892 to 1927. It contains data for 44 localities and gives the unallocated catches of the district in an additional section. Certain catches were combined as follows: Black Island and Black Islet under the name first used; Boca de Quadra catches include fish from Breezy Cove, Badger Bay, Sockeye Creek, and a part of the salmon reported from "Boca de Quadra, Behm Canal, and Chomly Sound" in 1911, part from "Smeaton Bay, Boca de Quadra, and George Inlet" in 1915; and part from "Smeaton Bay, Behm Canal, and Boca de Quadra" in 1912; "Bald Island" catches were added to those from Bold Island; salmon from "Carr Inlet," "Carl Bay," and Gnat Cove were counted as Carroll Inlet catches; Cone Island catches were combined with those from Cone Point; Felice Strait data include fish from Dog Island, Cat Island, and Pond Bay; Nasaler Harbor salmon were added to those from Hassler Harbor; and Cape Fox Village catches were combined with those from Kirk Point. The unallocated catches were increased by the inclusion of the salmon from 15 minor localities, as follows: Dixon Entrance, Nettie Island, Tongass George Creek, Custom House Cove, Hill Creek, Sandy Bay, Gravina Point, White Reef, George Inlet No. 8, Quadra Point, Seal Cove, Niquette Point, Cascade Inlet, George Inlet Packing Co. trap no. 1, and Morse Cove.

The runs of salmon in the Revillagigedo Channel district come mainly from Dixon Entrance and strike the shore in large numbers at many points between Tree Point near Cape Fox and Mountain Point on the west side of the entrance to George Inlet. Large catches were made by traps in these localities, as shown by the data for Point Alava, Black Island, Bold Island, Foggy Bay, Foggy Point, Kah Shakes Cove, Kah Shakes Point, Slate Island, Tongass Narrows, and Tree Point. These data show clearly that a heavy migration moves northward along this entire shore and that the catches were substantially as large in the northern part of the district as they were in the southern part. Moreover, large numbers of salmon left this route of migration to enter Boca de Quadra, Thorne Arm, Carroll Inlet, and George Inlet. Fairly large catches were also made along the eastern shore of Annette Island.

The fisheries in very few localities in this district are sufficiently distinct and separate from the general fisheries of the district as to make individual consideration of them worth while at this time. Of those which are fairly distinct, that of Boca de Quadra is the most important. Fishing began here with the exploitation of the red salmon at Sockeye Creek. In 1898 coho and pink salmon were taken for the first time. Eight years later chums were taken, but kings were not reported from this locality before 1917, the catches always being small and probably made by traps at the entrance of the bay. The catch of reds, cohos, pinks, and chums is shown graphically in Figure 50.

This graph shows that the red-salmon fishery was most productive in the period from 1895 to 1912. A sharp decline came in 1912 and 1913, which brought the catch from an average of approximately 100,000 down to about 20,000. In 1918 a further decline took place, and from then to 1927 the annual catch has averaged less than 10,000. The reduction of the catches probably resulted in part from the closing of all waters within 500 yards of the mouth of Sockeye Creek on January 1, 1916, in order to conserve the runs for fish-cultural purposes, since the Northwestern Fisheries Co. was then and is still operating a hatchery on a tributary of Hugh Smith Lake, of which Sockeye Creek is the outlet. This is the only stream tributary to Boca de Quadra that supports an appreciable run of red salmon. On January 1, 1925, this

locality was protected further by the prohibition of fishing within 1 mile of the mouth of the creek.

The pink-salmon fishery reached its maximum production in 1913. With the exceptions of 1918 and 1922, the catches since then have been relatively small, indicating depletion unless the reduction can be traced to the effect of trap fishing along the coast from Kah Shakes Point to Tree Point. The tagging experiments near Cape Fox in 1926 demonstrated conclusively that traps in that locality caught a high percentage of Boca de Quadra red and pink salmon. It is a reasonable conclusion, therefore, that traps at Foggy Point and Kah Shakes Point did likewise. Therefore,

FIGURE 50.—Catch of coho, chum, pink, and red salmon in Boca de Quadra, 1895 to 1927.

while the data unquestionably show that fewer pink salmon were captured in Boca de Quadra after 1913 than before that year, they cannot be taken as convincing proof of depletion of the fishery. The decline may be correlated with the increase in the number of traps in this section of the Revillagigedo Channel district, since all of them doubtless draw upon these runs.

The catch of chums has shown wide and apparently inexplicable fluctuations. The peak of production occurred in 1924, but since then the catch has dropped rapidly until fewer than 3,000 were reported as taken in Boca de Quadra in 1927. Prior to this the catch had been fairly uniform from 1908 to 1920, although a very small catch

was made in 1913, and 1917 saw one of the best catches ever made in this locality. It has been pointed out above, however, that the catch of chums is, in general, affected by numerous economic factors so that the fluctuations here noted may have no biological significance.

The coho fishery is not especially important. The largest catches were made in the years from 1907 to 1912. Since 1917 this fishery has produced less than 2,000 cohos annually, except in 1926, when 3,442 were taken.

Carroll Inlet produces fair runs of pink and chum salmon and small numbers of the other species. All species were more abundant in the 6-year period from 1922 to 1927 than in any earlier period of similar length in the history of the fisheries here.

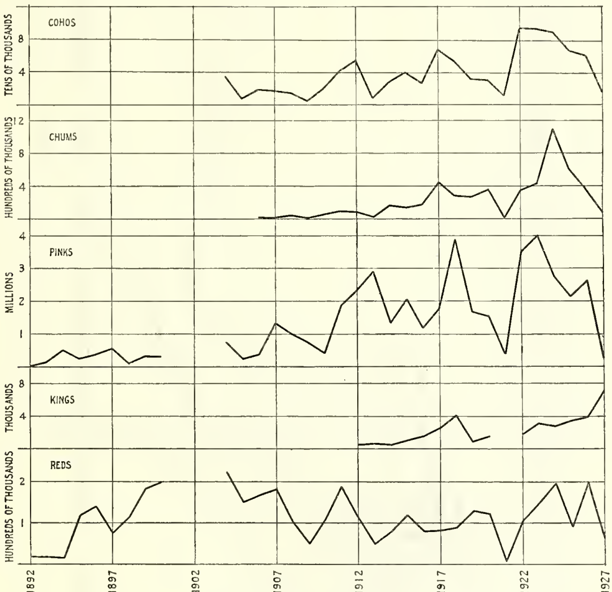

FIGURE 51.—Catch of salmon in the Revillagigedo Channel district, 1892 to 1927.

The earlier records are, however, incomplete, as no data were available for 1909 and 1912, which may occasion some doubt as to the productiveness of the respective periods, but, be that as it may, the Carroll Inlet fisheries appear to have suffered no depletion in the 23 years that they have been exploited.

George Inlet was fished as early as 1892 for its red salmon. The catch, always small, was consistent until 1916, when it fell off to less than half the previous figures, and has not increased subsequently, except in 1919, when the catch approached the level of the best years in the early development of this fishery. The catch in 1919, however, is open to question, as in the same year 392 king salmon were reported from this locality, although in all the earlier years of fishing in the inlet kings apparently

had not been taken. Presumably an error was made in allocating to the inlet fish taken by traps in outside waters. The catches of pink, chum, and coho salmon all

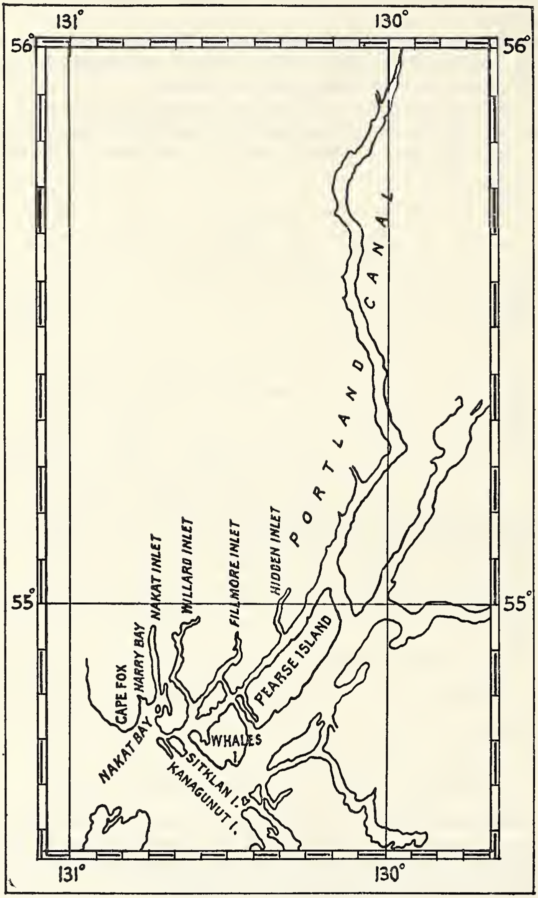

FIGURE 52.—Map of the Nakat Bay district.

show improvement in recent years down to 1926, but in that year and in 1927 they were smaller, a condition that may have been brought about to some extent by the closing of the inlet north of Tsa Cove and Bat Point on January 1, 1925.

The fisheries of Thorne Arm reached their highest productiveness in the four years from 1923 to 1926. Apparently there was some change in the character of the fishing, as this sudden increase in the catches and the evenness of the trend through these years indicate a considerable trap fishery in this locality in that period.

The salmon fisheries of the Revillagigedo Channel district in its entirety appear to be in a flourishing condition as late as 1927. In fact there was no period in the complete history of the district when all species of salmon, except reds, were taken in larger number than in the five years from 1922 to 1926. Although this period was also fairly productive of red salmon, this species was more abundant from 1900 to 1908 than in any later period. The many restrictions that were applied to fishing in the shortening of the season, the closing of certain areas, and the limitation in size of nets did not appreciably reduce the catches, but they undoubtedly held the production down to lower levels than otherwise would have been recorded. The catches are shown graphically in figure 51.

NAKAT BAY DISTRICT

The Nakat Bay district covers the waters between Cape Fox and the head of Portland Canal, a narrow body of water which, with Pearse Canal, extends inland in a northerly direction approximately 90 miles and forms the boundary between the southeastern extremity of Alaska and Canada. (See fig. 52.) The streams of the district are small and tributary to Nakat, Willard, and Fillmore Inlets and Portland Canal southward from Tombstone Bay. These localities have been fished chiefly by seines, while the mainland shore between Cape Fox and Harry Bay and the southern shores of Sitklan and Kanagunut Islands were fished largely by traps.

It appears from available data that fishing commenced in this district at Nakat Bay in 1906, at Sandfly Bay in 1907, and at Fillmore Inlet in 1908. All salmon from this district, except possibly some small lots that may have been pickled, were packed at plants in other districts until 1911, when a cannery was built on Hidden Inlet. Another cannery was opened on Nakat Harbor in 1912. Thereafter until both canneries were destroyed by fire in 1920, the catches went mostly to these plants, but as these canneries were not rebuilt the catches in this district have since been packed elsewhere.

TABLE 27.—*Salmon caught and fishing appliances used in the Nakat Bay district, 1906 to 1927*

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Boat Rock:												
1920	----	30,000	2,000	----	1,000	----	----	----	----	----	----	----
1922	1,840	1,897	51,769	----	459	----	----	----	----	----	----	----
1923	2,624	4,326	93,192	35	4,704	----	----	----	----	----	----	----
1924	2,042	7,517	116,272	23	5,549	----	----	----	----	----	----	----
1925	1,917	16,706	94,264	55	5,202	----	----	----	----	----	----	----
1926	811	8,641	36,846	----	8,967	----	----	----	----	----	----	----
1927	225	3,609	7,181	167	1,567	----	----	----	----	----	----	----
Dixon Entrance:												
1912	----	12	16,422	----	406	----	----	----	----	----	----	----
1924	139	103	6,382	4	478	----	----	----	----	----	----	----
1926	299	6,040	6,406	----	890	----	----	----	----	----	----	----
Fox, Cape:												
1912	1,461	1,486	42,980	----	2,068	----	----	----	----	----	----	----
1917	3,589	7,238	33,452	123	1,388	----	----	----	----	----	----	----
1918	2,149	4,518	131,472	----	2,966	----	----	----	----	----	----	----
1919	2,827	13,403	109,960	30	14,945	----	----	----	----	----	----	----
1920	2,574	7,912	88,202	14	6,701	----	----	----	----	----	----	----
1921	90	45	5,062	----	12	----	----	----	----	----	----	----
1922	6,803	4,162	218,411	----	6,620	----	----	----	----	----	----	----
1923	2,046	7,230	104,182	----	6,411	----	----	----	----	----	----	----
1924	4,992	16,118	209,981	150	13,139	----	----	----	----	----	----	----

TABLE 27.—*Salmon caught and fishing appliances used in the Nakat Bay district, 1906 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Fox, Cape—Continued												
1925	9,121	43,498	158,700	412	16,315							
1926	2,265	6,832	113,742	733	16,211							
1927	1,339	11,405	35,957	361	7,171							
Fillmore Inlet:												
1908	200	1,029	58,847		281							
1911	2,242	2,762	95,552		6,102							
1912	1,118	5,373	167,367		576							
1914	1,081	14,491	136,442									
1915	147	6,221	240,148		7,568							
1916		231	352		916							
1917	1,391	25,434	174,141	4	4,113							
1918	448	14,720	134,425	16	1,690							
1919	83	6,907	22,450		568							
1920	107	4,512	35,372		394							
1922	486	12,481	228,671		484							
1923	821	23,950	94,528		2,036							
1924	233	17,308	273,238	1	724							
1925	19	7,849	8,269		310							
1926	50	6,709	40,182	7	1,741							
1927		79	2,665		75							
Fools Point:												
1926		1,136	2,199		4							
Gamut Point:												
1925	1,936	11,538	40,952	71	4,320							
Garnet Point:												
1926	1,221	10,430	75,941	34	8,559							
1927		525	5,085		435							
Harry Bay:												
1912	625	432	69,147		1,500							
1914	525	429	8,311		186							
1917	81	572	33,017		77							
1918	106	72	15,847		2							
1919	16	46	4,912									
1922	7	357	23,081									
1925	200	7,000	12,200	25	100							
Hidden Inlet:												
1911	1,000	900	150,000	4								
1912	500	7,796	205,658		7							
1916	457	693	46,692		19							
1917	1,543	97,730	41,163		920							
1918	68	22,933	38,331		64							
1919		6,279	17,560	1	41							
1920	6	607	12,611	3	358							
1922		590	3,962									
1923	20	24,238	124,180	1	223							
1924	16	36,452	47,018		26							
1925		13,210	105									
Kanagunut Island:												
1917	5,271	11,463	248,444	389	10,975							
1918	7,036	13,901	291,137	56	5,407							
1919	12,014	31,026	262,375	1,250	38,707							
1920	6,472	82,301	229,366	411	17,281							
1922	7,160	5,615	251,715	206	7,858							
1923	12,137	22,560	433,550	303	26,190							
1924	5,226	27,880	271,262	51	17,999							
1925	5,344	30,816	154,420	157	12,997							
1926	2,181	20,184	176,500	21	15,844							
1927	1,910	8,561	57,555	182	8,310							
Lincoln Channel:												
1923		2,483	24									
Lord Island:												
1918		502	2,591		90							
1927	161	1,535	2,982	58	1,614							
Nakat Bay:												
1918	2,083											
1919	525	1,884	27,227	13	3,308							
1923	454	3,092	52,860		1,246							
1924	1,020	11,012	152,191	1	4,272							
1925	556	5,589	23,432	1	1,195							
1927	76	1,236	11,353	7	849							
Nakat Inlet:												
1906			5,040		8,260							
1907			2,405		17,043							
1908	240	1,733	43,371		29,983							
1909	142		12,277		3,148							
1910	95	1,705	4,223		28,444							
1911	792	1,557	42,163		19,463							
1912	917	573	35,968		11,533							
1914					4,415							
1915	129	3,779	188,714		7,071							
1916	269	1,673	10,473		2,194							
1917	232	959	2,858		2							

TABLE 27.—*Salmon caught and fishing appliances used in the Nakat Bay district, 1906 to 1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Nakat Inlet—Continued												
1918	42	109	9, 176		415							
1919			1, 767		634							
1920	5	5, 991	1, 808		2, 828							
1922	312	6, 942	3, 870		1, 278							
1923	927	17, 450	30, 237	1	1, 852							
1924	2, 729	22, 046	305, 291	1	8, 965							
1925	628	14, 375	52, 513	25	2, 665							
1926	152	9, 094	25, 569	1	636							
1927	24	1, 245	8, 138	2	439							
Pearse Canal:												
1912		67	153									
1918		5, 154	10, 576	9	99							
1919		935	1, 594									
1920	160	12, 576	42, 768	152	240							
1922	486	4, 113	101, 039		340							
1923	314	9, 314	85, 841		107							
1924	244	3, 720	90, 033		396							
1925	69	3, 245	1, 783	208	27							
1926	3	485	5, 723		15							
1927	45	283	1, 944	3	194							
Portland Canal:												
1912	1, 000	1, 400	19, 000									
1916	5, 478	49, 531	714, 244		2, 529							
1917	14, 654	57, 879	360, 741	300	18, 533							
1918	1, 965	26, 931	161, 183	399	4, 617							
1919	3, 485	2, 441	7, 042		337							
1920		990	1, 878	30								
1922			1, 161									
1923	36	1, 807	6, 742		264							
1924	16	5, 053	6, 299		2							
1927		140	1, 670	2								
Sandfly Bay:												
1907		114		4								
1917	590	26, 268	41, 552									
1918		6, 934	13, 648	5	63							
1919		1, 200	2, 750									
1923	31	1, 846	46, 934									
Sitklan Island:												
1917	930	3, 172	26, 647	61	991							
1918		3, 654	58, 035		719							
1919	1, 139	5, 501	41, 188	60	5, 660							
1920	931	31, 783	7, 291	3	901							
1925	594	5, 636	29, 153	8	1, 367							
1926	3, 250	9, 735	41, 979		4, 536							
1927	526	3, 283	29, 964	71	508							
Tombstone Bay:												
1916		1, 173	3, 157		58							
1917	4, 000	67, 516	95, 371	2								
1918	1, 994	92, 693	38, 308	83	28							
1919	62	45, 763	21, 796									
1920	3	15, 066	16, 744	2	3							
1922	161	20, 229	30, 034									
1923	416	31, 475	193, 627		88							
1924	90	14, 714	136, 152		418							
1925	5	34, 109	5, 890		3							
1926	12	29, 318	30, 775	50	26							
1927	2	758	5, 516		3							
Tongass Island:												
1923	5	18	761		512							
1926	2	86	468		118							
1927	125	1, 475	12, 214	21	1, 420							
Tongass Passage:												
1916	120	277	6, 473		242							
1925	936	8, 897	46, 572	8	2, 172							
1927	41	294	2, 301	2	347							
Willard Inlet:												
1912		805	35, 252		181							
1915	28	5, 091	64, 731		140							
1916		95	56		35							
1918	92	512	6, 236									
1919		3, 406	2, 645									
1922	13	652	29, 878									
1923	4	1, 219	6, 418		76							
1924	19	5, 377	93, 309		61							
1925		330	237		7							
1926	101	3, 719	14, 015	13	1, 573							
Unallocated:												
1909	360		87, 000		1, 500							
1913		8, 800	378, 328		2, 009							
1919	236	3, 882	18, 780		748							
1925		246		287								
1927					213							

TABLE 27.—*Salmon caught and fishing appliances used in the Nakat Bay district, 1906–1927*—Continued

Year	Coho	Chum	Pink	King	Red	Beach seines		Purse seines		Gill nets		Traps (number)
						Number	Fathoms	Number	Fathoms	Number	Fathoms	
Total:												
1906			5,040		8,260			1				
1907		114	2,405		17,043			1	200			
1908	440	2,762	102,218		30,264			3	570			
1909	502		99,277		4,648			2	355			1
1910	95	1,705	4,223		28,444			2	370			
1911	4,034	5,219	287,715	4	25,565			4	700			
1912	5,621	17,944	591,947		16,271			11	2,375	5	500	4
1913		8,800	378,328		2,009			5	750			
1914	1,606	14,910	144,753		4,601			8	1,200	4	200	
1915	304	15,091	493,593		14,779			15	2,480			1
1916	6,324	53,673	781,447		5,993			29	5,010			2
1917	32,281	298,231	1,057,386	879	36,999			21	4,250			5
1918	15,983	192,633	912,965	568	16,160	2	90	22	4,445			12
1919	20,387	122,673	542,046	1,354	64,948			16	2,875			21
1920	10,258	191,738	438,040	615	29,706			10	2,200			11
1921	90	45	5,062		12			1	250			
1922	17,268	57,038	943,591	206	17,039			9	1,500			8
1923	19,835	151,008	1,273,076	340	43,709			8	1,400			3
1924	16,766	167,300	1,707,428	231	52,029			17	1,985			14
1925	21,325	203,044	628,490	1,257	46,680			5	1,000			22
1926	10,347	112,409	570,345	859	59,120			11	2,045			15
1927	4,474	34,428	184,525	876	23,145			5	930			16

NOTE.—No catches were reported in the years not shown in any division of this table.

Table 27 gives the entire catch in the Nakat Bay district. It lists 22 localities, 11 of which have been fairly large producers of salmon. Here, as in other districts, certain combinations of catches seemed advisable; they are as follows: Cape Fox catches include salmon that were taken at Cape Fox Island; Fillmore Inlet was credited with half of the salmon reported jointly from "Fillmore Inlet and Nakat Inlet" in 1915, the other half being included with the fish from Nakat Inlet; Slim Island fish were added to those from Harry Bay; Monday Bay salmon were counted in the catches at Nakat Bay; Portland Canal data include fish that were caught at Halibut Bay and at Breezy Point. The unallocated catches were increased further by the addition of all salmon that were reported from Nakat Island, Tongass Village, Sunday Bay, and Port Tongass. The entire catch in this district in 1913 was reported as coming from "Nakat, Hidden, Fillmore, and Willard Inlets" and is shown, therefore, in the unallocated section of the table.

There were three periods of marked development of these fisheries. The first period began in 1911 with the establishment of the Hidden Inlet cannery and reached a peak in 1912 when a cannery at Nakat Harbor was put into operation. During the next 2 years smaller catches were made. In 1915 the second period began and culminated in a much larger production of all species in 1917, the total yield being 1,425,776 salmon. The catches of pink salmon dropped regularly in the next 4 years, but wide fluctuations occurred in respect of the other species. King and red salmon were taken in larger numbers in 1919 than ever before; chums dropped in 2 years but recovered in 1920; and cohos were more abundant in 1919, but not equal to the catch in 1917. The third period began in 1922 and progressed in the next 2 years until a total catch of 1,943,754 salmon was made, the increase being due to a greater number of pinks that were caught in 1924, a new high level for this species. Kings, cohos, and chums were taken in much smaller quantities than in 1917, the year of the second peak of production, but they reached comparable levels in 1925. There was a sharp falling off in the catches of cohos, chums, and kings in 1926, while that of pinks was far less severe. On the other hand, the take of red salmon increased

and closely approached the level of 1919. The catch of all species, except kings, dropped abruptly in 1927.

The smaller catches after 1924 were caused in part, at least, by the prohibition of fishing for a period of 27 days from August 18 to September 14 in each year, by

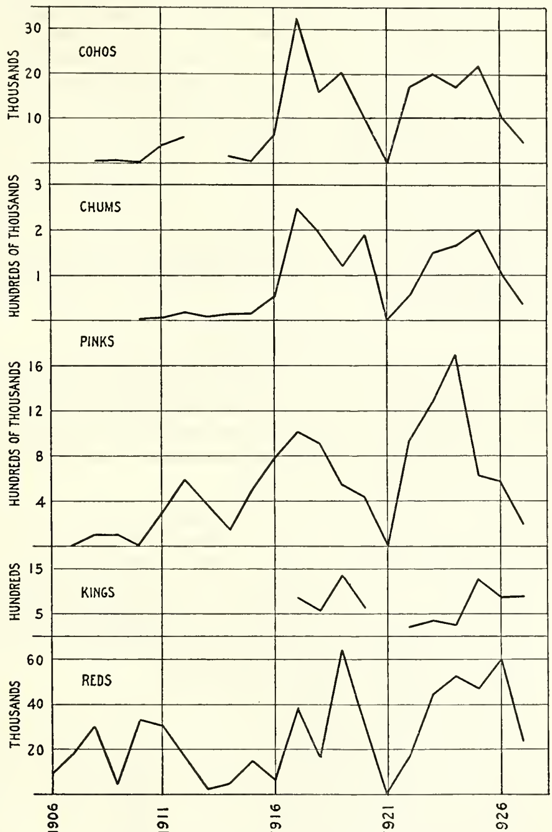

FIGURE 53.—Catch of salmon in the Nakat Bay district, 1906 to 1927.

the limitation of the size of nets, by the elimination of some traps, and by the closing of the waters of Hidden Inlet north of 55° N. latitude on January 1, 1925, and of Fillmore Inlet east of 130° 30′ W. longitude on January 1, 1927.

There seems to be little reason to doubt that the main runs of salmon to these fisheries come through Dixon Entrance rather than through Clarence Strait. Tagging

experiments near Tree Point in 1926 showed that out of 308 recaptured red salmon 27 were reported from the Nakat Bay district, 54 were taken in British Columbian waters, 192 from Revillagigedo Channel localities, 24 from Behm Canal, 10 from Clarence Strait, and 1 from Chatham Strait, thus demonstrating that the red-salmon runs along this shore are moving northward, 227, or 74 percent having been recaptured north of the place of tagging. Of the 81 fish that were taken south of Tree Point, one third of them came from Alaskan waters, chiefly from traps on the southern shore of Kanagunut Island, the remaining two thirds being reported from Canadian waters. This experiment also covered the tagging of cohos, pinks, and chums. Of the 41 cohos that were recaptured, approximately 50 percent came from the waters of British Columbia, while 7 percent were reported from the Nakat Bay district. Only 1 pink salmon out of 26 that were retaken came from this district; it was caught at Cape Fox. More than 7 percent of the tagged chums were retaken in the district, the greater part of which came from traps at Garnet Point on Kanagunut Island.

The data for the Nakat Bay district are shown graphically in figure 53 and show no serious decline in the productiveness of these fisheries. When viewed in the light of the restrictions which have been imposed here there is little reason to assume that any real change has occurred.

UNALLOCATED

Table 28 gives the unallocated catch of salmon in southeastern Alaska as a whole. These data represent the catches that were reported by many operators who gave no information as to the localities from which the fish were taken, thus making it wholly impossible to show a definite allocation. In practically all of the tables showing the catch by districts a section was included giving the unallocated catch in each particular district, none of which is included in this table.

TABLE 28.—*Unallocated catch of salmon in southeastern Alaska, 1893 to 1927*

Year	Coho	Chum	Pink	King	Red
1893	256,000			6,000	127,000
1894	331,000			6,000	117,000
1895	589,551				148,242
1896	39,999	2,938	634,023	3,958	114,284
1897	94,529		1,154,627	5,759	
1898	122,760	27,732	888,646	8,364	191,641
1899	138,036	6,500	1,367,463	12,284	268,809
1900	175,767	30,702	2,214,020	5,668	261,899
1901	108,582		5,355,659	5,527	388,886
1902	82,215		5,286,118	2,476	582,592
1903	279,844		3,908,391	36,000	553,359
1904	42,588	68,992	1,355,749		59,286
1905	3,000	449,300	97,812	13,300	
1906	21,565	32,401	574,672	12,720	12,034
1907			83,610	10,930	5,189
1908	23,523	21,212	960,012	18,798	18,200
1909			135,000	41,628	
1910	8,657		106,326	69,837	2,100
1911	24,276	54,879	1,006,356	4,868	43,691
1912	6,426	18,837	113,350	180,840	5,850
1913	25,650	31,692	530,338	93,860	9,843
1914	7,479	66,610	204,789	123,943	2,676
1915	81,876	105,476	2,338,833	59,737	72,917
1916	129,588	240,429	1,481,950	80,101	76,031
1917	22,168	291,510	1,309,788	18,825	18,331
1918	63,687	230,687	3,370,023	103,356	92,636
1919	70,526	211,099	519,042	199,670	49,218
1920	129,536	390,146	1,119,735	97,317	95,536
1921	98,982	135,457	1,294,071	156,443	25,984
1922	83,213	36,729	370,682	132,527	40,296
1923	110,980	168,080	1,739,917	155,546	71,949
1924	102,193	156,498	589,575	288,274	31,835
1925	153,728	168,359	821,662	223,073	26,341
1926	195,650	334,596	293,656	173,825	27,767
1927	152,239	26,343	10,457	253,812	4,409
Caught by lines (included in above):					
1905				2,434	
1906				12,720	
1907				10,930	
1908				18,798	
1909				41,628	
1910				69,837	
1911				4,868	
1912	5,118			180,840	
1913	20,025			84,395	
1914	2,860			123,332	
1915	63,061			55,709	
1916	30,878			79,113	
1917	12,100			18,687	
1918	31,607			102,214	
1919	58,706			199,510	
1920	109,632			96,474	
1921	55,855			155,916	
1922	56,861			131,772	
1923	24,260			155,542	
1924	92,212			288,155	
1925	142,218			216,580	
1926	152,851			155,522	
1927	69,815			250,949	

NOTE.—The data for 3 years, 1893 to 1895, are incomplete as they represent the catches by 1 company only. No other records were available.

TOTAL SOUTHEASTERN ALASKA

Although southeastern Alaska includes many regions in which the salmon runs are more or less distinct and which have been treated separately above, it is of interest to look at the district as a whole and to try to form some idea of the development and present tendencies of its salmon fisheries. The data are presented in tables 29 and 30.

TABLE 29.—*Total catch of salmon in southeastern Alaska, 1883 to 1927*

Year	Coho	Chum	Pink	King	Red	Year	Coho	Chum	Pink	King	Red
1883	----------	----------	----------	--------	107, 800	1906	659, 220	1, 374, 459	7, 036, 374	42, 084	2, 620, 860
1884	----------	----------	----------	--------	143, 000	1907	502, 646	1, 354, 929	11, 973, 899	89, 149	2, 201, 071
1885	----------	----------	----------	--------	26, 400	1908	457, 860	1, 824, 637	13, 592, 326	101, 160	2, 544, 671
1886	----------	----------	----------	--------	118, 724	1909	332, 376	699, 381	9, 497, 508	113, 886	2, 791, 461
1887	----------	----------	----------	--------	298, 491	1910	646, 065	1, 996, 840	9, 425, 310	175, 604	2, 986, 886
1888	16, 267	----------	----------	--------	436, 257	1911	901, 838	2, 784, 721	21, 408, 907	147, 168	2, 896, 988
1889	11, 246	----------	92, 094	--------	738, 146	1912	1, 099, 442	5, 342, 331	22, 011, 191	405, 780	3, 018, 060
1890	43, 915	----------	----------	--------	886, 734	1913	577, 189	2, 459, 777	25, 295, 606	353, 110	2, 218, 591
1891	23, 744	----------	----------	--------	943, 559	1914	914, 809	5, 444, 154	12, 567, 376	339, 004	3, 501, 203
1892	15, 371	----------	8, 197	--------	784, 959	1915	870, 535	3, 593, 040	30, 351, 380	281, 962	2, 825, 543
1893	256, 817	----------	186, 994	6, 000	744, 225	1916	1, 587, 607	4, 741, 634	19, 940, 350	256, 082	2, 381, 350
1894	347, 400	----------	528, 634	13, 000	719, 845	1917	1, 469, 396	6, 851, 774	40, 327, 465	327, 292	2, 622, 899
1895	609, 156	----------	605, 847	12, 747	893, 316	1918	1, 629, 366	9, 352, 573	39, 287, 711	411, 435	2, 821, 198
1896	241, 405	2, 938	1, 629, 819	18, 739	1, 572, 687	1919	1, 804, 005	9, 268, 489	24, 330, 891	579, 921	3, 262, 799
1897	267, 739	6, 683	3, 372, 564	25, 235	1, 129, 474	1920	1, 148, 051	8, 613, 368	18, 121, 431	351, 789	2, 743, 624
1898	291, 509	27, 732	1, 561, 301	16, 929	1, 237, 451	1921	911, 568	1, 846, 832	7, 735, 444	446, 310	1, 498, 933
1899	280, 679	7, 000	2, 912, 474	37, 039	1, 550, 811	1922	1, 258, 885	3, 728, 616	24, 001, 889	344, 852	1, 900, 123
1900	297, 555	32, 952	4, 321, 349	16, 734	2, 049, 011	1923	1, 342, 071	3, 912, 562	39, 879, 249	790, 461	2, 410, 357
1901	281, 440	----------	7, 525, 090	17, 361	1, 363, 825	1924	1, 214, 898	7, 266, 500	30, 029, 343	836, 004	2, 506, 115
1902	235, 461	----------	8, 100, 699	11, 664	2, 076, 647	1925	1, 211, 862	8, 188, 085	28, 246, 398	600, 102	1, 843, 518
1903	653, 569	----------	5, 528, 547	42, 474	2, 060, 581	1926	1, 184, 658	6, 105, 808	32, 193, 383	452, 920	2, 044, 708
1904	517, 856	358, 378	5, 178, 207	37, 118	3, 416, 470	1927	1, 284, 537	2, 219, 770	8, 163, 332	627, 201	1, 444, 563
1905	398, 981	1, 660, 981	3, 060, 358	68, 613	2, 610, 549						

TABLE 30.—*Fishing appliances used in southeastern Alaska, 1904 to 1927*

Year	Beach seines		Purse seines		Gill nets		Traps (number)	Year	Beach seines		Purse seines		Gill nets		Traps (number)
	Number	Fathoms	Number	Fathoms	Number	Fathoms			Number	Fathoms	Number	Fathoms	Number	Fathoms	
1904	49	--------	168	--------	281	--------	18	1916	16	1, 988	436	77, 363	296	29, 250	219
1905	71	--------	133	--------	192	--------	29	1917	35	4, 380	563	101, 645	412	60, 798	302
1906	65	--------	157	--------	208	--------	30	1918	120	13, 708	729	138, 153	411	48, 037	363
1907	49	6, 120	186	31, 865	136	22, 505	31	1919	156	17, 415	766	153, 740	239	42, 825	416
1908	57	8, 265	208	35, 970	186	34, 605	58	1920	107	12, 605	572	108, 405	337	39, 055	474
1909	47	6, 490	137	24, 600	125	25, 870	38	1921	46	5, 250	144	25, 615	229	44, 850	107
1910	51	6, 615	208	40, 163	247	42, 350	53	1922	24	3, 000	568	97, 755	255	27, 425	241
1911	57	7, 645	243	46, 595	430	78, 560	85	1923	23	2, 325	590	105, 091	239	19, 666	320
1912	126	17, 385	362	72, 797	404	57, 510	164	1924	21	2, 270	768	137, 649	198	17, 395	325
1913	86	12, 419	308	58, 437	271	49, 300	142	1925	9	950	613	110, 166	158	18, 271	409
1914	57	9, 070	368	68, 428	227	34, 790	166	1926	8	720	825	155, 273	189	26, 900	483
1915	31	3, 988	410	73, 326	120	16, 750	180	1927	8	1, 250	415	75, 122	157	20, 509	576

In any consideration of the condition of a fishery it is important to know as much as possible of the changes in fishing effort. In the case of the salmon fisheries of southeastern Alaska, however, there have been such great and general changes in the nature of the gear used as to make any reliable evaluation of the changes in fishing effort virtually impossible. Some of these changes are apparent in the data presented in table 30 and in the accompanying figure (fig. 54), but these refer only to the number of units of each kind of gear that have been employed and give no notion of the great changes in effectiveness that have come about. There has probably been little change in effectiveness of beach seines and gill nets but these are, on the whole, of relatively slight importance in southeastern Alaska. Traps and purse seines account at present for a very large percentage of the total catch in this district and both of these forms of

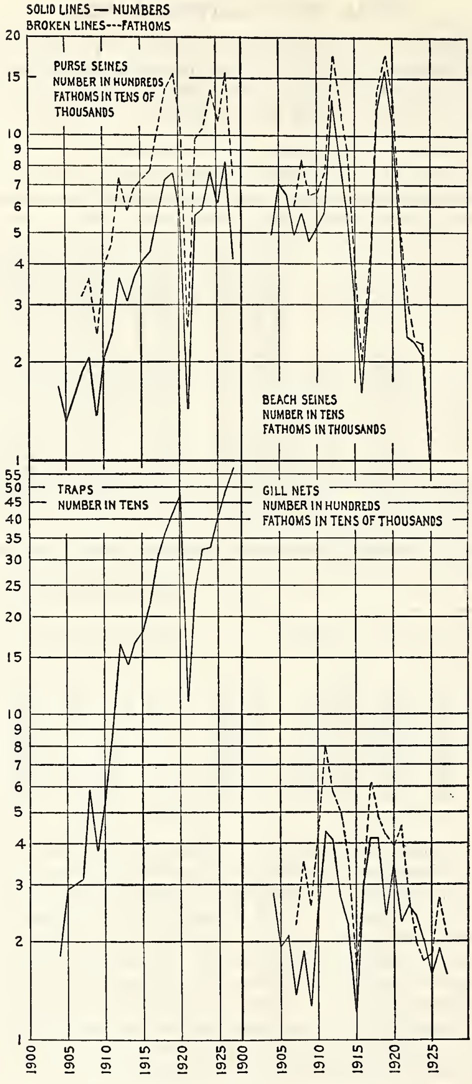

FIGURE 54.—Gear used in southeastern Alaska, 1904 to 1927.

gear have undergone marked development during the period under consideration. In the case of purse seines there has been, perhaps, not so much change in the character and effectiveness of the nets themselves as in the boats from which they are operated. In general these boats are larger and much better powered now than in the earlier years in spite of recent regulations which have limited the size of boats which may be used in purse seining. In the case of traps, improved construction has made it possible to operate successfully this apparatus in exposed positions that could not possibly have been used before and the development of the floating trap has made trap operations possible in places where pile traps could not be driven. Some of these improvements are reflected in the increased number of traps, but there have been general improvements in trap construction which have probably effected the relative efficiency of practically all traps in the district and which cannot possibly be measured. It is safe to say, however, that both traps and purse seines have been increasing gradually in effectiveness as fishing units.

The changes that have taken place in respect of the types of gear used have been notable. They are shown graphically in figure 54 as ratio diagrams so that the relative changes in the use of the different forms will be clearly shown. (In a ratio diagram of this sort equal slopes indicate equal relative changes.) It is apparent that the number of beach seines and gill nets in use has been greatly reduced in recent years while the number of traps and purse seines steadily and rapidly increased from 1904 to 1920. The reduced fishing effort in 1921, which has been mentioned repeatedly above, is shown clearly by the greatly reduced number of all forms of gear in use in that year. Since 1921 the number of purse seines used, up to 1927, was about the same as in the years 1916 to 1920, and the number of traps increased regularly until more were operated in 1926 and 1927 than in any previous year.

While it is clear enough that important changes have taken place in the character of these fisheries it is obviously impossible, with the data at hand, to arrive at any satisfactory conclusion as to the effect that these changes have had upon the real intensity of fishing. There can be no doubt that this intensity has increased enormously, but the lack of any information as to the relative effectiveness of the different types of gear, of the relative effectiveness of the same type of gear at different times, and of the effect of competition between units of gear as the number has increased make it quite impossible to measure the changes in intensity of fishing as a whole.

Turning now to a consideration of the total catch of each species in southeastern Alaska it is apparent that different tendencies are shown by the different species. The total catches are shown graphically in figure 55 which, like the graph showing the changes in gear, is presented as a ratio chart so that relative changes may be correctly inferred.

The catch of red salmon increased rapidly between 1885 and 1890 and formed by far the most important product of the fishery up to about 1895. For the next 10 years the catch of this species continued to increase and then for 15 years, up to and including 1920, maintained a fairly constant level; 1921, as usual, showed a greatly reduced catch and from 1922 to 1927 the average catch was not much more than half that for the period 1905–20. The catches since 1921 doubtless have been affected somewhat by the regulations, but in view of the undoubted increase in the intensity of fishing, the fact that the catch of other species was increasing rapidly during the time (1905–20) that the catch of reds was relatively constant and that the

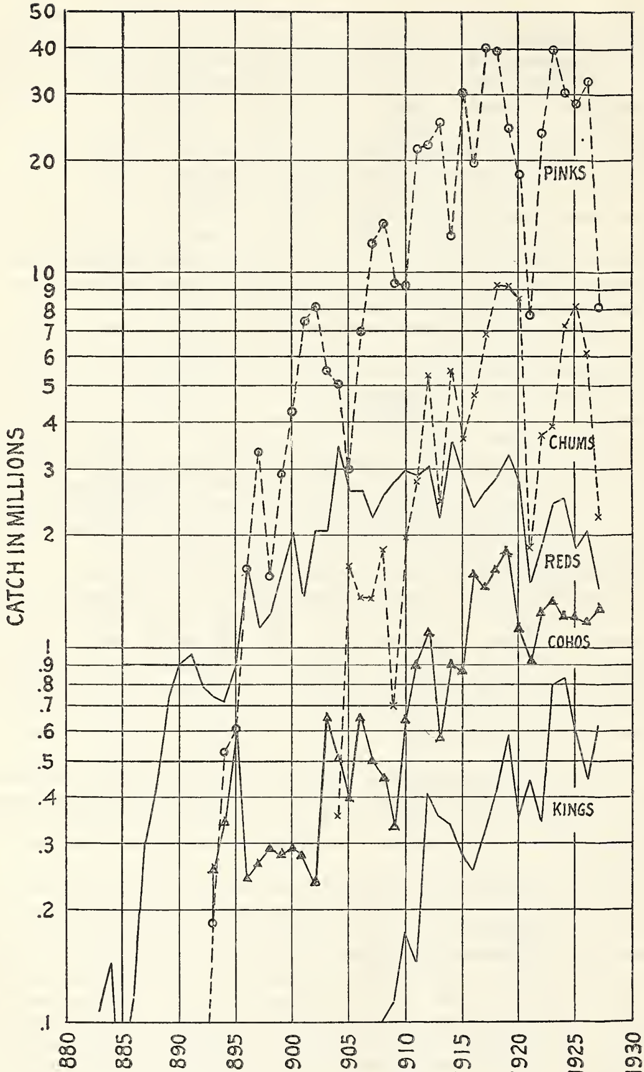

FIGURE 55.—Catch of salmon in southeastern Alaska, 1883 to 1927.

catch of other species since 1921 has shown no similar decrease there can be little doubt that the red-salmon runs of southeastern Alaska are depleted.

The catches of pinks and chums show a very similar growth. Pinks did not become an important element in the catch until about 1895 and chums not until about 10 years later. Once these two species appeared in the catch, however, their importance increased with great rapidity. More pinks have been taken than of any other species in every year since 1895 and, with the exception of pinks, more chums have been taken than of any other species in every year since 1911. The increase in the catch of these two species continued with minor fluctuations up to about 1917 and 1918, and since then has remained fairly constant except for the 2 poor years of 1921 and 1927.

There is some evidence of a negative correlation between the catches of these two species, in other words there appears to be a tendency for the catch of chums to be smaller in years when many pinks are taken, and vice versa. From a study of the selling prices of these two species [11] it is clear that the prices of chums and pinks are parallel—chums running usually only 5 or 10 cents lower than pinks, and it would appear as though pinks and chums were interchangeable in the market. If this be true the catches of each might be regulated, in part at least, by the abundance of the other species. It seems probable, however, that the catch of chums is regulated by the abundance of pinks rather than the reverse since pinks are slightly more valuable and tend, on the whole, to run somewhat earlier in the season.

The tendencies toward a negative correlation show chiefly in certain parts of the curves—that is, 1911–16 and 1922–26. These are the only parts of the curve that have not obviously been disturbed by known factors: The period from 1904–10 was one in which the fisheries for these species were developing and the available supply obviously greatly exceeded the demand. The catches in 1917 and 1918 were tremendously increased by the extraordinary war-time demands; in 1921 the catch was greatly reduced as a result of low prevailing prices and a large "carry over" from 1919 and 1920, when the pack had been large in spite of the reduced demand following the close of the war, and in 1927 the runs of both species were exceedingly poor for unknown but probably biological reasons. On account of the fragmentary nature of these data it has not seemed desirable to attempt a statistical analysis of this apparent negative correlation—we here merely point out the probable existence of such a relationship.

The catch of cohos shows a fairly steady increase from about 1895 to 1920 and remained remarkably constant during the last 6 years here considered, 1922 to 1927, inclusive. The catches during these 6 years have been slightly lower than during the war-time years from 1916 to 1919, but, with this exception, have been greater than at any previous time in the history of the fisheries. On account of the fact that this species tends to run later in the year than any other it is, generally speaking, not as intensively fished and the resources have evidently been able to provide for the gradually increasing demand.

A still different condition exists in respect of the king salmon. The catches have continued to increase quite rapidly throughout the period under discussion. Previous to 1912 the total catch in any year did not exceed 200,000, but since that time it has increased quite regularly and has only twice—in 1915 and 1916—fallen below 300,000.

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[11] As shown by the "opening prices" tabulated in the various editions of the Annual Statistical Number of the Pacific Fisherman and in Pacific Salmon Fisheries by John N. Cobb, 4th edition, Report of the U.S. Commissioner of Fisheries for 1930 (1930), pp. 409–704, Washington.

This constant increase in the catch of this species has been due undoubtedly to a corresponding increase in the amount of trolling, in which type of fishing kings and cohos are taken almost exclusively. It has been mentioned above (p. 575) that tagging experiments have shown that many of the kings taken by troll off the coast of southeastern Alaska and British Columbia are native to the Columbia River and to a lesser extent to the rivers farther south. It is impossible to say to what extent local races enter into the catch, but there can be little doubt that the southern fish, particularly those of the Columbia River, form an important element in the catch and have made possible this constant increase. Under such conditions the conservation of this species in southeastern Alaska is not at all a local matter, but is intimately involved with the troll fishery off the coasts of British Columbia, Washington, Oregon, and California, as well as the important fisheries in the Columbia River.

The Columbia is undoubtedly the most productive stream in the world so far as king or chinook salmon are concerned and evidently dominates the catch throughout at least the northern part of the western coast. The Columbia River runs have been fished intensively for many decades and show unmistakable signs of depletion in spite of artificial propagation which is probably unparalleled in extent and efficiency; the spawning areas have been greatly reduced by the erection of dams and the drain on the resources has been gradually increased by the development of the fishery in the river and more recently by the increase in trolling. The future seems doubtful and a continuation of the increase in the catch of kings in southeastern Alaska seems most unlikely, although certainly there is no indication of reduced catches in the data herein considered. If this valuable fishery resource is to be preserved, however, a complete and detailed study of all the influences that bear upon the maintenance of the Columbia River kings should be undertaken without delay.

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[Roman numerals indicate the several parts which compose this review]

GENERAL INDEX